BULLETIN

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THE INSTITUTE OF PHYSICS

AND

THE PHYSICAL SOCIETY

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Appointments Vacant

The inclusion of particulars of a vacancy must not be taken to imply that the Institute and Society necessarily approves of the terms offered or that might be offered. Candidates should satisfy themselves that these are satisfactory, and they may always refer to the Institute and Society for advice.

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BUILDING RESEARCH STATION

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United Kingdom Atomic Energy Authority

and

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Within the laboratory this group will be responsible for:

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(*b*) The small scale production of such equipment.

and (*c*) The maintenance and supply of most of the electronic equipmment which is used in the Rutherford Laboratory.

The Leader of the Group will also be generally responsible for liaison with the Electronics Division of the Atomic Energy Research Establishment which is engaged in the long range research and development of electronic apparatus. Applicants should have a first or good second class honours degree, or its equivalent, in Physics or in Electrical Engineering and should have several years experience in research or development work in the field of electronics. A knowledge of nanosecond pulse circuitry and experience in the use of transistors would be a recommendation.

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Surgical Asepsis — A Physical Problem

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[Based on a lecture to the Scottish Branch, given in Dundee on November 15, 1960]

THE SITUATION

LET US observe at once that successful surgery depends on successful team work: operating surgeon, anaesthetist, nursing and auxiliary staff, backed by the hospital engineer, pathologist, pharmacist and even physicist, must all work together, taking those special pains which arise from proper understanding of a common task, if a surgical unit is to do consistently good work. The problems of surgery are therefore among those which require the methods of operational research, with the participation of workers from the various different disciplines concerned, for their effective treatment. Thus in isolating problems of special physical interest we give a very partial view of this important branch of technology.

Just now (November 1960) in Glasgow our medical colleagues are celebrating the centenary of the appointment of Joseph Lister as surgeon in charge of those wards of the old Royal Infirmary where he later revolutionized surgery by the introduction of antiseptic methods—essentially, the use of certain vigorous poisons for killing dangerous micro-organisms. At the time of Lister's appointment, the vast increase in major surgery which had followed the introduction of effective and fairly safe anaesthesia had been checked by as vast an increase in the fatal hospital gangrene. With antiseptic precautions, hospital surgical wards became almost safe places.

Unfortunately, most antiseptics are also poisonous to human flesh, and when antiseptic dressings of extensive wounds were found to delay healing and even poison the patient, the further refinement of aseptic technique was developed. The modern surgery of nerves and joints depends entirely on successful asepsis.[1] In this method the killing of microbes in air or other fluids, and on cloth, instruments and so on which may come in contact with the surgical wound, is referred to an earlier stage, and this killing should be performed by an agent which leaves no irritant or poisonous residue in the goods treated and does minimum harm to their useful properties.

Such an agent may be a volatile poison such as formaldehyde or ethylene oxide, but in surgical practice heat, in conjunction with varying concentrations of air and moisture, is by far most widely used. For some useful materials and implements which cannot endure the necessary heat, heavy doses of ionizing radiation may offer a preferable means of microbe-killing or sterilization.

An aseptic technique adequate for most surgical purposes was developed about 1900. Why then is asepsis a subject of much concern to-day? The two main reasons are penicillin and the National Health Service. Penicillin and its related antibiotics prevent the explosive multiplication of sensitive organisms, thus arresting them until natural protective reactions, even though enfeebled, have time to take effect. In the outcome they act as if they were antiseptics, though poisonous to few human beings. Thus the extensive use of antibiotics has permitted, while the conditions, first of war-time surgery, and then of the vastly increased volume of civil surgical work consequent on the inception of the Health Service, have enforced, some relaxation of the standards of aseptic technique.

Unfortunately, continued exposure of certain classes of micro-organisms, especially the normal flora of our external and internal surfaces, to small concentrations of antibiotics gives the correct conditions for flourishing populations of strains resistant to these antibiotics to develop. One particular organism, the *Staphylococcus aureus* which is responsible for most outbreaks of boils and pimples, and for worse things, has adapted with particular success, and strains resistant to all the common antibiotics are now more or less permanently resident in the throats and noses and on the skin of the surgical and nursing staff of most hospitals.

Moreover, the sterilizing methods and equipment in many of our hospitals, though formerly adequate, fail to deal properly with the new volume of work. One must consider what new equipment would be most efficient and economical. Thus surgical asepsis, although in one sense an old story, gives rise to a number of topical problems.

Interesting physical problems arise in the mechanics

of surgery and the processes of anaesthesia. One important issue arises from the inflammability of many anaesthetic vapours ; explosions have occurred often enough for anti-static precautions to be well worth while. In this article, however, we concentrate on problems of asepsis, especially of sterilization, that is, the killing of micro-organisms in various situations with minimum damage to the goods contaminated by their presence.

THE PROBLEM

Surgery requires the actual presence of at least two hopelessly septic objects—the patient and the surgeon—and often more. Asepsis therefore presents two problems:

(1) to prevent the flora of external and internal surfaces of patient and staff from entering the wound (even if the latter is already septic, though additional problems then arise), and,

(2) to prevent any extraneous vegetation from entering the theatre (aseptic technique in the wards is another, though a related, problem).

To achieve the first of these it is necessary to confine the infected sweat and phlegm of anyone in the theatre by suitable clothing, including gloves and masks. Unresolved problems in this field include devising an objective test for the serviceability of used rubber gloves and devising a mask for the surgeon's nose and mouth which does not impede communication, is not so uncomfortable as to reduce his working efficiency, and still stops germs.

To achieve the second involves trapping or killing the organisms in fluids, both aerial and aqueous, in dressings —largely cotton textiles—and on instruments—of metal, glass, rubber and other plastic materials—without spoiling the utility of the articles. Trapping is effective only in the filtration or distillation of fluids, thus for most purposes we are concerned with the killing of bacteria, a subject of which astonishingly little is known in detail.

THE ENEMY

Bacteria are minute single-celled plants, of the order of a micron in diameter, capable in favourable circumstances of explosive multiplication by binary fission. Their presence is normally recognized by this multiplication in a suitable culture medium : multiplication in us is also necessary for serious consequences to follow a small infection, so a cell which cannot divide is effectively dead for both purposes even if it can still metabolize and even grow in size.

Like other living cells, bacteria contain a wide variety of chemical substances of which the most easily damaged in isolation, and so plausibly the most readily attacked in the cell by non-specific lethal agents, are the high polymer nucleic acids and proteins. There is a wide gap between showing that an agent produces a potentially lethal chemical effect and showing that its lethal action is due to this effect. This gap is still in most instances wide open.

Many pathogenic bacteria are highly specialized as parasites and correspondingly easy to kill outside the very stable environment of the human body. Some common ones, however, especially those accustomed to live in soil with gross fluctuations of temperature and humidity, are adapted to resist adverse circumstance by forming a dormant phase or spore which is remarkably resistant to dry heat or ionizing radiation. This endurance may be due to a reduced or re-organized water content, but its biochemistry is very little understood. Since dressings, dusting powders and so on are often contaminated with the spores of the common bacteria responsible for lock-jaw and gas-gangrene, any sterilizing system must at least deal effectively with these. The usual test requirement is that it must deal with the even more resistant spores of an organism (e.g. *Bacillus stearoth rmophilus*) which prefers rather high temperature for its ordinary vegetative existence.

BACTERIAL SURVIVAL RATES

The simplest conditions in which to study bacterial survival are (*a*) at constant temperature, or (*b*) under a constant intensity of radiation. The humidity must also be constant for consistent results to be obtained, except in the rather special case of a slow ionizing particle, with a correspondingly high density of ionization (what might be called the Edward II method of execution). For a technical sterilizing process one requires a penetrating radiation—essentially, fast electrons, even if the initial irradiation is by gamma rays—and no more need be said of the densely ionizing particles here.

The results of experiments under both sets of conditions are simple and surprising.[2,3] The number of survivors (able to form visible colonies by multiplication on a suitable medium) diminishes exponentially, with a time-constant independent of the initial concentration. If one has a homogeneous initial population, this implies quite clearly that during the treatment, the likelihood of any survivor dying in the next short interval is independent of the time for which it has already been exposed. This result arises obviously from a " one hit theory " for radiation : a " one-hit theory " for the simple cooking process seems less plausible.

However, experiments on the effects of heat and radiation applied together and alternately (to yeast cells) show synergic effects which suggest that there is a largely reversible preparatory stage of damage followed by a single irreversible lethal event, and that heat and radiation, at least in the last stage, attack the same cell constituent, almost certainly the genetic apparatus. This last suggestion is confirmed by the behaviour of diploid yeasts, which have a double set of genetic equipment and can apparently multiply even if one set is knocked out.

The exponential death curve of bacteria suggests that most of the cells in bacterial populations are haploid. A genuine inhomogeneity of population has been found in several organisms where the last thousandth or so of the initial population die, still more or less exponentially, but much more slowly than the rest. These resistant cells, however, give rise to a normal population when they multiply. Very little is known of other properties correlating to resistance : it is conceivable that bacteria not usually considered spore-formers have nevertheless a similarly resistant stage in their life cycle.

For our purpose, the vital point in this is that, short of combustion, no treatment can be specified which will kill *all* cells in a given sample with complete certainty. A given " sterilizing " treatment produces attenuation by a definite factor in each bacterial population exposed

to it, and a "safe treatment" is one which, from an initial population larger by several decades than any infection which can reasonably be expected in practice, leaves an expectation of finding any survivor which is below, say, one per cent. A patient would have to be in a catastrophically low state of resistance to develop a recognizable disease from so small an infection as some tens of cells, and indeed in such a condition would probably succumb to his own normal flora.

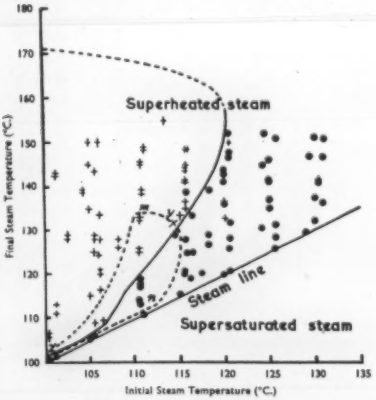

Fig. 1. *Treatment of heavily contaminated specimens at various degrees of superheat. Crosses mark the discovery of surviving organisms. (From Savage, 5, 6, with acknowledgments).*

The literature contains a number (surprisingly small) of accounts of treatments which did sterilize contaminated samples of various sorts.[3] The canners and manufacturers, with a real financial incentive, have done rather more work than the health services. Recommended sterilizing treatments are based on these results with a random succession of safety factors. Present recommended practice[4, 5] with steam sterilizers rests to a considerable extent on the work of Dr. Maxwell Savage,[6] whose elegant, economical resolution of a well-defined problem, and its successful application in production, constitute a model of technological research. An important group of his data is summarized in Figure 1, illustrating how the death of some heat-resistant spores depends on humidity. Only a small amount of superheat is tolerable.

Other conditions being constant, the thermal death rate of a population increases by equal factors for equal intervals of temperature rise. Over the rather narrow usable band of temperatures, this approximates to the behaviour of a process with a single activation energy, and the typical factor of 10 for a ten Centigrade degree temperature interval corresponds to an energy of 3 ev., which is decidedly large for the types of reaction one might have expected to be involved. A great deal of further work is needed.

To summarize, the following are generally regarded as adequate sterilizing treatments :—

(*a*) exposures to saturated steam at, for example, 132°C for two minutes or at 121°C for 12 minutes ;

(*b*) irradiation[7] with 2 to 5 megarads of γ-rays or fast electrons.

The next problem is their selection and application.

DEATH AND DAMAGE

Having found a range of processes which will kill germs satisfactorily, choice among them depends on the ability of the lethal agent to reach the germs and on the relative damage done by the processes to the articles being sterilized. Articles whose cavities are inaccessible to steam must be sterilized either by the slow and very damaging dry heat of an oven, or by ionizing radiation with enough energy to ensure penetration. Rubber and most plastics cannot endure dry heat, especially if oxygen is present, so irradiation is the only safe way to sterilize complicated articles made of these materials.

For substances accessible to steam (and not destroyed by it) the temperature of treatment may be adjusted to minimize damage. Time of treatment is the prime consideration for only one purpose—emergency sterilization of instruments—and instruments likely to be needed in emergency will almost all endure, and be sterilized by, two minutes exposure to flowing saturated steam at 132°C or above. A small sterilizer made for this special purpose will not, however, deal with dressings.

Fibrous materials, whether loose, spun or woven, are usually contaminated before or during manufacture, and, now that germ-proof wrappings such as heat-sealed polythene film are easily to be had, there is a great deal to be said for leaving the manufacturer with the responsibility for sterile supply of materials which are used once only, such as dressings. This responsibility is already accepted for such things as cat-gut sutures. For the near future dressings will continue to be sterilized at the hospitals along with repeatedly used articles like towels and rubber gloves.

Animal materials such as sutures and grafts of dead tissue, which serve a continuing structural purpose in the surgical wound, lose their usefulness especially rapidly under severe sterilizing treatments. While grafts may be taken in aseptic conditions, and cold stored in the presence of antibiotics, silk and gut are in principle contaminated and minimum sterilizing treatments checked by bacteriological tests of frequent samples are essential for them. If one can be certain, as is seldom possible, that contamination is present only on the exposed surface of a specimen, then of course a destructive but *non*-penetrating sterilizing agent may be used. A convenient and effective agent of this sort is ultra-violet light in the wave-band 2300 to 2800A, spanning the nucleic acid absorption centred on 2600A. and overlapping the protein absorption at 2800A.

Vegetable fibres used in surgery, almost exclusively cotton and linen, are needed primarily to absorb water and aqueous solutions. The British Pharmacopoeia test for surgical gauze is that a gramme mass compressed to about 20 ml. and laid lightly on water at 20° should be

saturated within 10 seconds. This high capillarity is obtained apparently by a vigorous scouring and bleaching treatment which raises the susceptibility of the material to heat damage, the bleaching adding a factor of about 3 to the rate of tendering.

I am indebted to Dr. P. S. H. Henry for information[8] on the loss of strength of cotton under heat treatment. The rate of tendering is taken inversely as the time for a standard (e.g. 50%) loss of tensile strength in constant conditions. In the interesting temperature range of 100 to 150°C the rate of tendering increases by a factor of roughly 2½ for every 10° rise in temperature. It increases by only about 20% from relative humidity 90% to R.H. 99%, but is very sensitive to the presence of air, dropping by a factor of ten when air is removed.

Since the thermal death rate of bacteria has a much higher temperature coefficient than the tendering of cotton and is not thought to depend much on air pressure, it appears that, for minimum damage, sterilization of cotton goods should be carried out at the highest convenient temperature and in the absence of air.

Surgeon and nurse require their dressings not only sterile but dry. Damp sterile dressings and gloves must be dried, then, and in many hospitals this is done by a current of warm infected air, giving an end-product which is nominally "sterilized", and in fact both damaged and infected. This is inexcusable, however customary.

Since gloves are inhomogeneous articles it is not easy to set numbers on their rate of destruction by heat. Present evidence is that the deterioration of rubber is even more sharply dependent on the air present than is that of cotton, and that a great deal of the damage to gloves occurs during drying rather than sterilization.

AIR, STEAM AND COTTON

The first reason for getting the air out of goods being sterilized is not so much to reduce oxidative damage as simply to get the steam in. The necessary heat for raising the goods to sterilizing temperature is brought in by the steam, primarily as latent heat. If we are presented with a mixture of air and steam, condensation from this can take an article to no higher temperature than the dew point of the mixture at its surface.

Now consider what happens at a cooler surface, such as the door of the sterilizer pressure vessel. Steam condenses and air does not. If convection is suppressed, a nearly steady state may be reached, in which the rate of delivery of heat to the cool surface is determined by the diffusion of steam through an air barrier, or, which is the same thing, by the reverse diffusion of air away from the surface. The mutual diffusivity of air and steam at 120°C and 2 atmospheres pressure is about 0·2cm²/sec.

In the usual case of a vertical door surface, the cool air-rich layer glides down, and, unless special care is taken to heat the base of the chamber and obtain a convective re-mixing, a deepening stratum of relatively cool (but often unsaturated) air forms at the bottom. This mode of separation of air from steam is familiar to heating engineers and can be dealt with by draining away the air through a thermostatic valve set at the end of a foot or two of unlagged piping from the lowest point in the chamber. The same drain also handles the condensed water. It should not be directly connected to the hospital sewage system, but has occasionally been found to be so. Hospital plumbers must be told about asepsis, like everyone else.

With this sort of arrangement any air which is free to circulate in the chamber is removed without doing great harm. Air trapped inside the load is another matter. The load of a hospital sterilizer is often packed in metal drums, of typical size twelve inches across by ten deep. When (usually) the volume of work being attempted is too great, the drums are overfilled and closed by the weight of the largest available nurse. The resulting almost solid block of textile resists most steam sterilizing procedures with complete success, since application of steam under pressure simply produces a large bubble of warm air in the centre of the block and this can drift out only very slowly under its own weight. Another relevant fact is that the hygroscopic fibres tie down the water, so to speak, and the effective mutual diffusivity of the air and steam is enormously reduced ($\sim 10^{-4}$cm²/sec) towards the diffusivity arising from surface transfer alone.[9,10] If really wet steam is used, water at some temperature will reach many parts of the load by capillary transfer, but it is generally beyond human wit to dry the resulting sodden mass without contaminating it.

Evidently it would be a good idea to remove the air by a vacuum pump before admitting the steam. The cost of pumps and of the N.H.S. being what they are, we must know what determines the limiting vacuum required. Here the humidity of the British climate comes for once to our aid. Cotton which has been kept in this country for any length of time has equilibrated in a high average relative humidity and will evolve water vapour freely as soon as the surrounding pressure falls to the pressure of water vapour in equilibrium with the fibre. Unless the material has been deliberately dried, then, this "boiling out" of water vapour will sweep the air from even a densely packed drum if the total pressure in the chamber is reduced to something below 10 mm. Hg. Experiments by Knox and Penikett,[11] and others, show successful sterilization of deliberate overloads at pressures slightly higher than this, but a systematic exploration of temperature and humidity effects is still desirable.

As a result of the very small diffusivity of heat and moisture in the textile, the process of adsorption of water is nearly reversible.[12] Consequently, if a vacuum of the same order is drawn after sterilization, the load returns to its initial cool and dry condition, provided the steam supply has not been too wet. This eliminates the secondary drying with all its attendant risks of damage and contamination. For the second vacuum, where only steam is being withdrawn, a water jet pump is ideally economical, but a rotary pump of several h.p. is needed for the air extraction, and it may be simpler to use it for the steam as well.

The interaction of cotton and steam at sterilizing temperatures has not been properly explored. To examine what may happen we extrapolate from the experimental results (Figure 2) of Urquhart and Williams.[13] Evidently the latent heat of adsorption of water on cellulose is higher, but not vastly higher, than that for

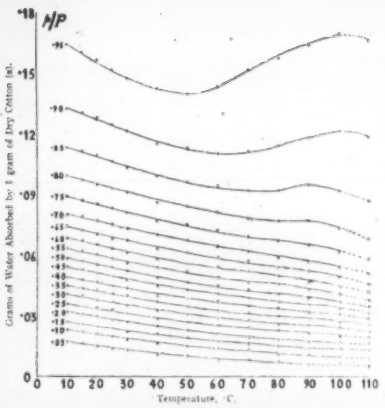

Fig. 2. *Water content of soda-boiled cotton as a function of temperature and relative humidity. (From Urquhart and Williams, 13, with acknowledgments).*

water on water. As one might expect, the difference is of the order of the latent heat of fusion. The apparent reversal above 85% R.H. needs to be explored. It is likelier that true equilibrium is not being reached at the lower temperatures than that the latent heat varies so much.

In any case, simple minded and slightly less simple minded extrapolation agree in predicting that, for example, a cotton load starting at 20°C, with a water content between 5 and 8% of its dry weight, and exposed to dry steam initially at 130°C will end internally in equilibrium with a relative humidity of 90% and a temperature of 133°C. Completely dry cotton would superheat by 8°. Dr. Savage[5] reports uniformly successful sterilization at 3° superheat, but more bacteriological information would be needed before one would risk running much higher. Superheat, however, would only be a real risk if (*a*) dry steam were being expanded in to the chamber from much higher pressure (the Joule-Thomson effect is not large in the probable range), or (*b*) a steam jacket were being run substantially hotter than the chamber steam itself, or (*c*) the load were unusually dry and warm to start with.

Experience so far[12] suggests that steam with 10% wetness can be used without unpleasantly wet dressings being delivered. This also needs exploration since few hospital steam lines provide steam as dry as this.

AIR FILTERS AND STERILIZERS

By the processes outlined in the last section we have our load of dressings agreeably cool, dry and sterile, on the other side of a large iron door held shut by an atmospheric thrust of the order of three tons. Air must be let in to the chamber to free that door, and it had better be sterile air.

Any good air-conditioning plant which removes fine dust from the air does a great deal to disinfect it, and air of this quality may be acceptable for an operating suite if the local farmer has not just manured a field to windward. For sterilization, more drastic treatment is needed.

Water and carbon dioxide are the only gas components of air with a substantial infra-red absorption, so a flood of thermal radiation will destroy suspended particles without much heating the air. "Air burners" for this purpose do exist. The efficiency of this system could in principle be improved by mounting a pair of blowers back to back to provide a region of high pressure and temperature between them, and use electrical heat only as a boost, but such a system would probably only work well at high power. Ten air changes per hour are as much as is necessary or comfortable in working rooms.

Whatever is done about the general air supply, the circulation of septic articles and persons makes it necessary to take local precautions at the sterilizer air inlet. Since air is needed in considerable but intermittent flow, filtration seems to be the best expedient. Filters of glass paper[14] are now commercially available which will pass less than one in a million of the spores of *Bacillus subtilis*. They are cheap and good, and should rapidly replace the lumps of blackened cotton wool frequently found when autoclave "filters" are inspected.

The mechanism of filtration brings us back to a fascinating series of physical problems.[15] At this scale, a filter does not work like a quarry screen, but contains many channels larger than the particles which it traps. These reach the walls either by Brownian motion or by branching of the flow, and adhere by electrostatic or van der Waals forces. The mean square displacement per unit time, in a given direction, of a particle of radius a at temperature T is

$$(1 + \lambda/a)kT/(3\pi\eta a)$$

where η is the viscosity of the air and λ the mean free path of the air molecules. The λ/a term, which contains the whole pressure dependence of the expression, is uncertain by about 30%. For a sphere of a micron diameter, the mean square displacement per unit time in a plane is about 10^{-6}cm^2/sec. so it cannot have a substantial probability of wandering sideways by more than its own diameter in less than several hundredths of a second. Consequently, Brownian motion will contribute little to trapping unless the air spends at least this time in the filter. For the thin glass paper filters, then, trapping must be almost entirely by impact as the flow branches round the glass fibres. A theory of this process has been elaborated by Langmuir and more recent workers,[15] and is in no more than decent agreement with the facts.

CONCLUSIONS

In the present state of the art it is not hard to specify processes for the sterilization of various goods which not only are effective but do little damage, whether heat or more energetic radiation is employed. Understanding of the fundamental processes of bacterial death and material damage, on which any radical improvement of the processes must depend, is still to seek.

Argument still rumbles round questions of policy. For example, should hospital sterilizers be of a sort which

requires expert use but little maintenance, or of a sort which is nearly foolproof in use but requires expert testing and maintenance ? In present staffing conditions the second is the wiser choice, but a reliable indicator of failure to achieve sterilizing conditions, which at the same time is not too stringent in its demands, is then needed, and not yet developed.

Further developments will include the wider application of ionizing radiation, extended use of ethylene oxide in warm moist air, not discussed in this lecture, and probably an increased supply of disposable sterile articles in sealed packs from the manufacturers.

ACKNOWLEDGMENTS

I owe a great deal to the members of the Medical Research Council's working party on steam sterilizers, and especially to Professor J. W. Howie, the Chairman, for introducing me to these important and interesting problems. I am also specially indebted to Dr. P. S. H. Henry and Dr. I. Lominski for discussion and information. None of these gentlemen, unless they have published like views, must be presumed to share the opinions expressed, which are personal though on the whole, I believe, rationally founded.

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Professor H. L. Callendar

C.B.E., M.A., LL.D., F.R.S.

By

L. H. CALLENDAR

B.Sc., Ph.D., F.R.I.C., F.I.M.

HUGH LONGBOURNE CALLENDAR was born at Hatherop, Gloucestershire, April 18, 1863. He showed abnormal precocity with a quick understanding of languages. By ten years old he used to write Latin prose every morning before breakfast and he was also very good at mathematics. Perhaps his practical skill was most outstanding for, at about this age, he constructed a telegraph and quickly learnt the Morse code for sending messages about the house; he also made a Rhumkorf spark coil and a Wimshurst machine—and all this without any help at all.

MARLBOROUGH COLLEGE AND CAMBRIDGE

At eleven years old he obtained the first foundation scholarship to become the youngest boy in the school; he became Senior Prefect at 16 and stayed two years more before going to Cambridge. He won every prize for which he entered and became top of the school in Classics and Mathematics, yet he took an active part in all games and represented the school in gymnastics and shooting. He acquired a microscope and studied geology, botany and biology, preparing hundreds of beautifully mounted slides which he showed his children many years later. He took charge of a telescope given to the school and got parties of masters and boys to come on the roof at nights to see the stars when he explained to them the marvels of astronomy.

Invention started in his school days with a fountain pen before they were known, some of which were in use for sixty years. He devised and perfected later a system of shorthand still used by many people. He contrived an apparatus for recording simultaneously the direction and force of the wind and devised a system for testing sight and colour blindness by means of a spectroscope and invented a new kind of vernier telescopic rifle sight and won the Prince of Wales Cup at the Bisley Shooting Competition.

Anthony Hope, the writer, contemporary with Callendar at Marlborough, mentions in his memoirs, "Callendar, the Senior Prefect, was not only very popular but was looked upon with amazed respect because of his remarkable all-embracing intellect; in work he could do everything better than any of us could do anything and with such glorious ease".

Taking all available scholarships he went to Trinity College in 1882, reading Classics and Mathematics at the same time. In 1883 he was elected to a Bell scholarship, in 1884 he obtained 1st class Honours in Classics, in 1885 1st class Honours in Mathematics, and in 1886 he was elected a Fellow of Trinity for his already successful work in scientific research.

Although working 10-12 hours a day, including holidays, Callendar took two hours off whenever possible in the afternoons and was thus able to keep fit and excel at sport. He was in the University lawn tennis team; he became captain of the lacrosse team, represented the University at gymnastics and captained the University shooting eight.

SCIENTIFIC RESEARCH

Starting in the Cavendish Laboratory in October 1885, Professor J. J. Thomson suggested the problem of the metallic resistance thermometer. Thomson, in his autobiography, says that H. L. Callendar was the most brilliant of all his research students during 40 years teaching at Cambridge. He was "an intellectual 'Admirable Crichton' who did everything well. In less than eight months he obtained results of absolutely first class importance. He gave to physics a new tool to determine temperature with an ease and accuracy never before obtainable and he was the first to suggest, from his experiments, the existence of super-conductivity of metal at or about the absolute zero". Callendar also taught J. J. Thomson his new shorthand which he had invented at school and which Thomson continued to use all his life.

Callendar started his research of 1885 in the rather primitive conditions of those days, using a windowsill in a passage as his working bench. He read a paper on his results to the Royal Society on June 10, 1886, and patented his platinum resistance thermometer in 1887. For the standardization of his instrument against Regnault's gas thermometer, with typical invention, he

sealed his platinum spiral inside the latter. In 1928 the platinum resistance thermometer became the world standard for temperature measurement from −190°C to +660°C based on the formula which he had advocated from his experiments some 40 years before.

This instrument has contributed greatly to the progress of metallurgical engineering; with the Callendar platinum thermometer an accuracy of 0·1°C at 1000°C could be obtained in the determination of the melting points of metals. On this accuracy was based the classic work of Heycock and Neville [1] which has given a high standard to all later work in physical metallurgy and provided engineers with an ever increasing number of new metals and alloys as materials of construction.

Callendar platinum thermometers manufactured by the Cambridge Instrument Company were first used in metallurgical engineering in 1891 at one of the Mond Steel Works [2] and then at the Royal Mint under Professor Roberts-Austin to determine the melting point of gold and silver [3] and later by Sir Lowthian Bell who used the newly invented direct reading Callendar temperature indicator kept in a central position and connected by long cables to a number of platinum thermometers in his various blast furnaces [4].

The next Callendar invention of great importance to metallurgical-engineering was the recorder patented in 1897. It was the first electrical instrument using the servo principle [5] and thus the parent of hundreds of thousands of similar and derivative instruments used all over the world to-day. These recorders became widely used in engineering works, e.g. Lysaght's big sheet steel works at Newport, Mon., used 65 of these original recorders with platinum thermometers for controlling their furnaces, and some of them were in use for as long as 50 years.

To-day the uses of the platinum resistance thermometer are world wide, e.g. long distance passenger aircraft may carry up to 14 platinum thermometers and ships carrying frozen meat from the other side of the world may have nearly 100 platinum resistance thermometers for each ship [6].

From 1887-91 with his Fellowship of Trinity he was able to carry on his researches at Cambridge and at the same time study both law and medicine, including " walking the hospitals ". In 1889 he published his new " Cambridge System of Shorthand " and this came into some use both at home and abroad.

In 1890, Callendar arranged with Horace Darwin of the Cambridge Instrument Company to start to manufacture his various patents as they came along including the platinum resistance thermometer, the temperature indicator, the recorder, the precision resistance bridge, etc. In 1891, working entirely on his own, he made application for no less than nine original patents in different scientific fields, while at the same time taking up the post of Professor of Physics at the Royal Holloway College.

CANADA

In 1893 he was appointed Professor of Physics at McGill University, Montreal, Canada. At a welcoming dinner by the University staff, the Professor of Classics, starting a quotation in Greek extolling the humanities, unfortunately broke down; with an apology, Callendar stepped into the breach and finished his Greek quotation for him, suggesting that a scientist was not without a knowledge of the humanities!

The Professor took few holidays except for lacrosse, shooting and tennis in which he played for McGill University. Although he was giving a number of lectures he always felt happiest when engaged on research. Early research included the first development in 1896 of X-rays in Canada, he himself quickly making more than 30 X-ray tubes of different designs for test; he also gave public demonstration lectures which included the British Association and the B.M.A. on their official visits to Canada in 1897.

Perhaps his major research at this time was on the theory and practice of the steam engine. His paper on the subject with J. T. Nicholson, entitled " The Law of Condensation of Steam " when read to the Civil Engineers in London was hailed by the distinguished engineer, Professor W. C. Unwin, F.R.S. as the most important paper on the subject that had ever been presented to the Institution [7]. On the same line he introduced a simple and direct method of extreme precision, which has been copied by many subsequent investigators, for determining the total heat of steam using the differential form of the throttling calorimeter.

In 1898 he was offered the Chair of Physics at University College, London, but as he had already made McGill College famous, they tried to hold him in Canada by offering him the Professorship in Astronomy in addition to Physics at nearly double his salary. Wisely he decided to go to London. Rutherford, who succeeded him at McGill has left some private comments on the profound impression Callendar had left behind there.

> " McGill (to which I have been appointed) is a very important place for Callendar (the previous Professor) was an F.R.S. and a Fellow of Trinity and I will be expected to do great things. I think my appointment is a much discussed matter at Cambridge as Callendar was considered a very great man.
>
> " Callendar here " (Rutherford had now arrived at McGill) " was considered a universal genius and I gain a sort of reflected glory by carrying on with things Callendar alone was able to do. The trouble is that Callendar left such a reputation behind him that I have to keep rather in the background at present." (*Rutherford's Life and Letters*, Eve p. 54-68.)

There is no doubt that the high reputation that Callendar had made for McGill University physics was a powerful stimulating force to his successor Rutherford. Later, Callendar was an enthusiastic supporter of Rutherford's early work on radioactivity, and was partly responsible as a member of the Physics Committee of the Council of the Royal Society for electing Rutherford a Fellow in 1903.

With his professorship in London Callendar became a Fellow of the Physical Society in 1898 and was the Treasurer for ten years from 1900; in 1910-12 he became President. He continued his work on steam at University College and having already obtained the value of the adiabatic index and the total heat over a fair range of pressures, the problem was how to reconcile

them. In solving this he made a revolutionary change in the whole treatment of the properties of vapours which remains of fundamental importance. Previous investigators had published tables for the properties of steam in which necessary thermodynamic relationships of total heat, specific volume and pressure were ignored. In 1900, while Professor of Physics at University College, London, Callendar issued his equation for steam [8] and published the first thermodynamically consistent steam tables. To-day, thanks to Callendar, all other published steam tables follow his innovation and his own steam tables in enlarged form are still in use, 60 years later. He also showed that the variation of the specific heat of water is due to the fact that every liquid contains in solution its own volume of vapour. If its temperature is raised more vapour is dissolved and the specific heat of the liquid is increased by the latent heat of the vapour [9].

THE CONTINUOUS FLOW ELECTRICAL METHOD

The continuous flow method was invented by Callendar in 1886, developed at McGill 1895-1898, and described in his Bakerian lecture to the Royal Society in 1912 [10] entitled "Variation of the Specific Heat of Water, with experiments by a new method". This continuous flow system greatly reduced the major errors of the classic calorimeter method used by all previous scientists, such as the heat capacity of the apparatus, etc. and the heat losses were reduced to a minimum by enclosing the apparatus in a vacuum jacket. It was used for many purposes [9] but especially for his major investigations from 1920-30 on the nature of the critical state between liquids and gases.

In 1901 he contributed a paper to the Physical Society "On the Thermodynamical corrections of the Gas Thermometer" in which he was the first to make an accurate calculation of the absolute zero of temperature at 273·10 ± ·02°C [11]. At the same time he was writing articles for the *Encyclopoedia Britannica* on Heat, Thermodynamics, Calorimetry, Thermo-Electricity, Vaporization, etc., which appeared in various editions from 1902-1959. He was on the Council of the British Association for the Advancement of Science from 1900-1906 and President of the Mathematics and Physics section in 1912; he was on the Council of the Royal Society 1902-1904. Generally he avoided public offices of any kind, in spite of many offers, as they would cut down the time for his research work to which he felt himself dedicated.

From University College he moved to the Royal College of Science in 1902 and helped to design the new laboratories for Physics which were opened about 1906 and considered ahead of any others in the country at that time. In 1910 he invented a cup-type radio-balance to meet a request from Rutherford (now at Manchester) for means of measuring the heat produced from 1 mgm. of Radium and its emanation to about 1 part in a 1000.

EARLY SCIENTIFIC INTEREST IN THE MOTOR CAR

He obtained one of the first motor-cycles in the country and after fitting it with an 8-speed gear and a basket seat to carry one in front, made extensive tours all over the country and in Ireland where there were no garages or means of repair except the blacksmith's shop and his own engineering skill. He made many contributions to the early improvement of motor design, and established a scientific testing station under one of his staff, Dr. Watson, behind the Physics building at Imperial College. In 1904 he changed to a De Dion Bouton single cylinder car and fitted it up to hold five people and some luggage. In 1907 he bought a Stanley steam car, then the fastest car in the world, but because of the trouble of having to fill it with water every twenty miles and the frequent bursting of the boiler, he converted it into an air-car with the advantages of no trouble, no gears and very smooth running; after his death this was bought by the Science Museum, South Kensington, for exhibition.

As President of the Physical Society 1910-12 his first address "Electrical Recording Thermometers for Clinical Works" introduced a new instrument to medicine which has given many valuable results. In his second year as President his address in 1911 showed his unequalled ability to handle with ease the major basic problems of physics. This was entitled "The Caloric Theory of Heat and Carnot's Principle". In this he showed how the caloric theory if rightly interpreted was simply an alternative method of describing the same phenomena as the kinetic theory and was not opposed to it or to the law of conservation of energy. Caloric re-appeared under the title of Entropy introduced by Clausius and there was no real difficulty in explaining under the caloric theory the generation of heat by friction without loss of weight [12].

During the 1914-18 war he was Consultant to the Board of Inventions and Research and was later awarded the C.B.E. for work associated with the submarine detector and for adjudicating on various outside inventions.

After the war he was offered many other posts of a scientific and industrial nature both in Britain and in America but refused them all. The truth was he did not want to leave the Royal College of Science. Also he did not like industrial administrative work with its numerous time-wasting committees, which would interfere with the work he enjoyed most, his individual practical researches after new knowledge.

In 1920 his new treatise called *Properties of Steam and Thermodynamic Theory of Turbines* was published.

Following the publication of his book he acted as scientific consultant on several occasions to Parsons the Turbine inventor and manufacturer, and his research on steam received substantial industrial support through the Electrical Research Association so that he was able to design and set up suitable apparatus for the investigations at high pressure and temperatures up to the critical region.

In 1924 the Physical Society awarded Professor Callendar the first Duddell Medal.

From 1924 onwards he was encouraged to publish his major steam researches, first a description of his methods and apparatus in the journal *World Power* [13]. During this period American scientists from the Bureau of Standards came over to examine Callendar's apparatus [14] and their later results were in very close agreement with

Callendar's steam tables published 15 years earlier[15]. At the same time working for the Air Ministry on Engine Research in 1926 he published his new theory for the cause of "knock" and the mechanism of anti-knocking agents in petrol engines. Later the same year he gave an account of the progress of his steam researches in three Howard lectures to the Royal Society of Arts[16].

Callendar's final achievement announced in his Hawksley lecture to the Institution of Mechanical Engineers[17] just before he died was to carry his high pressure temperature experiments right up to the critical point for water and steam, which had never been done before. He then proposed three simple equations, consistent with the laws of thermodynamics, which should suffice to define all the properties of steam for international standard purposes and which should be of the greatest assistance both to the scientist and to the practical engineer.

In an obituary in *Nature*, Mr. H. M. Martin, wrote:—

"In all the major works which bear his name, he alone was responsible for every detail and every determination, yet he was ever ready to give his assistants more than full credit for anything they did. Perhaps his most valuable contribution to science was to raise the standard of everything he touched in physics or engineering beyond anything that had gone before."

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April 1961

The Teaching of Relativity

F. J. PEARSON
B.Sc., Ph.D., A.Inst.P.
Lanchester College of Technology, Coventry

THERE is an increasing tendency, in the teaching of modern physics to technologists, to have to make use of certain formulae from the Special Theory of Relativity. For example, when dealing with nuclear fission in an introduction to reactor physics for engineering students, it is often customary to quote the well-known $E = mc^2$ without proof. Similarly, reference is frequently made to the result $m = m_0/\sqrt{(1 - v^2/c^2)}$ in discussing atomic theory with, perhaps, chemists or metallurgists, but rarely is any attempt made to derive these formulae in such circumstances, on the grounds that it would then be necessary to make a comparatively lengthy digression into Relativity, and that this would be out of place in courses of study intended for non-physicists.

However, it is quite common practice to devote some attention to wave mechanics in courses of this nature, but it does not appear to be common knowledge that many of the familiar Relativistic equations can be easily derived during an exposition of the properties of de Broglie waves. The purpose of this note is therefore to give a brief indication of the essential argument involved.

One commonly begins the study of wave mechanics by referring to Einstein's introduction of the concept of a photon of energy E and frequency ν related by

$$E = h\nu. \tag{1}$$

This concept implies that, under certain circumstances, what had previously been thought of as an electromagnetic *wave* ought more properly to be regarded as a *particle*, and leads naturally to the converse question: whether a particle of mass m moving with velocity v can be regarded as a wave of length λ; and, if so, what the properties of this de Broglie wave would be. It is usual to postulate that:—

(*a*) the group velocity $-\lambda^2 d\nu/d\lambda$ equals the particle velocity v thus

$$-\lambda^2\, d\nu/d\lambda = v, \text{ and} \tag{2}$$

(*b*) equation (1) is satisfied in the non-relativistic form

$$E = h\nu = \tfrac{1}{2}mv^2 + U \tag{3}$$

where U is the potential energy of the particle. Differentiating equation (3) with respect to λ, we find that

$$h\, d\nu/d\lambda = mv\, dv/d\lambda. \tag{4}$$

Eliminating $d\nu/d\lambda$ between equations (2) and (4), integrating, and putting the constant of integration equal to zero, we obtain

$$\lambda = h/mv. \tag{5}$$

The legitimacy of assuming that the constant of integration is, in fact, zero can then be tested experimentally. All this is well-known, of course, and equations (1) and (5) are accepted as fundamental properties of the waves associated with particles. However, if we now postulate that they apply equally well to photons considered as particles moving with velocity c given by

$$c = \nu\lambda, \tag{6}$$

then from equations (1), (5) and (6) it is easily shown that

$$E = mc^2. \tag{7}$$

And if we accept that equation (7) describes the general equivalence of mass and energy, applying to both photons and material particles, and consider once again a particle of mass m, velocity v, energy $E = h\nu = mc^2$ and de Broglie wavelength λ, we can write

$$\lambda = h/mv,$$

and

$$\nu = mc^2/h$$

and hence

$$\nu\lambda = \frac{c^2}{v}. \tag{8}$$

Equation (8) gives the phase velocity of de Broglie waves. We can now write the above condition that the group velocity equals the particle velocity in the form

$$\frac{c^2}{v} - \frac{\lambda}{d\lambda}\frac{d}{d\lambda}\left(\frac{c^2}{v}\right) = v. \tag{9}$$

From equation (9) we find that

$$\frac{1}{\lambda} = \frac{kv}{(1 - v^2/c^2)^{\frac{1}{2}}}, \tag{10}$$

where k is a constant of integration. Then using equations (1), (8) and (10) we obtain

$$E = \frac{hkc^2}{(1 - v^2/c^2)^{\frac{1}{2}}} = mc^2. \tag{11}$$

Equation (11) enables us to identify hk with the rest mass m_0 of the particle, and leads immediately to the relativistic variation of mass with velocity given in equation (13) below.

Admittedly there is an apparent logical flaw in the argument sketched so briefly above, in that equation (3) is non-relativistic. However, if we now replace it by the more correct result

$$h\nu = mc^2, \tag{12}$$

with

$$m = \frac{m_0}{(1 - v^2/c^2)^{\frac{1}{2}}}, \tag{13}$$

then, differentiating with respect to λ, we find that

$$\frac{h\, d\nu}{d\lambda} = \frac{mv}{1 - v^2/c^2}\frac{dv}{d\lambda} \tag{14}$$

instead of the previous equation (4). But, on eliminating $d\nu/d\lambda$ between equations (2) and (14), integrating, and putting the constant of integration equal to zero, we once more regain equation (5), although the mass m is now given by equation (13). Consequently, equations (1) and (5) are still our fundamental equations.

Furthermore, it is possible to go on to derive other familiar relativistic formulae by this method. For example, using the concept that energy E is equivalent to force F times distance in the form

$$F = \frac{1}{v}\frac{dE}{dt} = \frac{1}{v}\frac{dE}{dv}\frac{dv}{dt}, \qquad (15)$$

then from equations (10), (11) and (15) it follows that

$$F = \frac{d}{dt}\left(\frac{hkv}{(1-v^2/c^2)^{\frac{1}{2}}}\right) = \frac{d}{dt}\left(\frac{m_0 v}{(1-v^2/c^2)^{\frac{1}{2}}}\right) = \frac{d}{dt}(mv), \qquad (16)$$

which is Newton's law in relativistic form, leading to the principle of the conservation of momentum.

The above equations (7), (11), (13) and (16) probably represent the most commonly used relativistic equations as far as most introductory atomic and nuclear physics courses are concerned. The virtue of this method lies in the comparative facility with which they can be derived from the basic ideas of de Broglie waves. It is not intended to supplant the more conventional treatment of the Special Theory of Relativity in the education of the professional physicist, although it has a certain intrinsic interest.

Appeal for the Physics Trust Fund

The following donations or subscriptions were received between February 23 and March 23, 1961:

(*a*) From Members

Mr. J. H. Aird
Mr. T. Ashton
Mr. J. R. Atkinson
Mr. J. W. Avery
Dr. V. Balashov
Dr. G. P. Barnard
Mr. A. E. de Barr
Mr. J. R. Beattie
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Mr. A. M. Dowler
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Professor P. P. Ewald
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(*b*) From firms

The Birmingham Small Arms Co. Ltd.
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Kearney & Trecker-C.V.A. Ltd.
The Mirrless, Watson Co. Ltd.
Permali Ltd.
Rubery Owen & Co. Ltd.
Triplex Safety Glass Co. Ltd.
Wolsey Electronics Ltd.

The total received or promised by March 23, 1961 (including those previously announced) was :

	£
Gross value of industrial firms' covenants over seven years (including tax recoverable)	98,878
Single donations from firms	7,450
Total from Industry ...	106,328
Gross value of 221 members' covenants over seven years (including tax recoverable)	4,858
Single donations (280) from members	746
Total from members ...	5,604
GRAND TOTAL at March 23, 1961	£111,932

Notes and News

Nominations for Members of Council

Members are reminded that the first Council of the amalgamated body was appointed by the Board of the Institute and the Council of the Society before amalgamation as a " caretaker Council " to hold office until September 30, 1961. Article 50 of the new constitution provides that they shall then retire, but shall be eligible for re-election.

The President and other Officers and the Ordinary Members of the Council are, if the Members wish, prepared to continue to serve for another year (that is until September 30, 1962) in order to be able to consolidate the work of the amalgamation which is now proceeding satisfactorily. Mr. A. J. Philpot, the Vice-President responsible for the exhibitions, is not standing for re-election and Council, in accordance with Article 71, has nominated Dr. V. E. Cosslett as Vice-President to succeed him. With regard to the two Chairmen of Branches on the Council, the Members are reminded (Article 47) that these seats are filled by the Annual Representative Meeting.

The provisions of Articles 60-67 for ensuring that there shall be regular changes in the personnel of the Council will, of course, become operative in 1962.

Accordingly, and in accordance with Article 71, Council now sends herewith to each Member notice of the undermentioned duly qualified persons whom it nominates as candidates for election to the said offices at the Annual General Meeting (July 4, 1961) to take office on October 1, 1961.

President

Sir John Cockcroft, O.M., K.C.B., C.B.E., M.A., D.Sc., F.Inst.P., F.R.S.

Vice-Presidents

V. E. Cosslett, M.A., M.Sc., Ph.D., F.Inst.P.
Professor R. W. Ditchburn, M.A., B.Sc., Ph.D., F.Inst.P.
W. H. Taylor, M.A., D.Sc., F.Inst.P.
J. Topping, M.Sc., Ph.D., F.Inst.P.

Hon. Treasurer

J. Taylor, M.B.E., D.Sc., F.R.I.C., F.Inst.P.

Hon. Secretary

C. G. Wynne, B.A., Ph.D., F.Inst.P.

Ordinary Members

Professor C. C. Butler, B.Sc., Ph.D., A.Inst.P.
E. R. Davies, O.B.E., B.Sc., F.Inst.P.
Professor B. H. Flowers, M.A., D.Sc.
J. M. A. Lenihan, M.Sc., Ph.D., A.M.I.E.E., F.Inst.P.
G. R. Noakes, M.A., F.Inst.P.
Professor C. F. Powell, M.A., Sc.D., F.R.S.
F. A. Vick, O.B.E., Ph.D., A.M.I.E.E., F.Inst.P.
Professor D. A. Wright, D.Sc., F.R.A.S., F.Inst.P.

Members are reminded of the terms of Article 72, which states:

" 72. After the notice mentioned in the last preceding Article, any five Members may nominate within two weeks of receipt by them respectively of such notice, but not later, any other duly qualified person as a candidate for election to any one or more of the said offices by depositing such nomination in writing at the office together with the written consent of the nominee to accept office if elected. No Member may nominate more than one candidate in any year for any one vacancy ".

Vice-President: Dr. V. E. Cosslett

Dr. Cosslett who has been nominated as a Vice-President of the Institute and Society was educated at the University of Bristol, the Kaiser Wilhelm Institute, Berlin, and University College, London. He obtained his Ph.D. at Bristol in 1932 and is also an M.Sc. of the University of London and an M.A. of both Oxford and Cambridge by Grace. Since 1949 he has been a University Lecturer in Physics at Cambridge. Dr. Cosslett is known internationally for his work in electron-microscopy and in developing the X-ray microanalyser. He is President of the Royal Microscopical Society.

Becoming an Associate of the Institute in 1939 and a Fellow in 1942, Dr. Cosslett was the first Honorary Secretary of the Electron Microscopy Group and was its Chairman from 1953-55. He served as a member of the Board of The Institute of Physics from 1959 until the amalgamation in 1960 and as a member of the Council of The Physical Society from 1956 until the amalgamation. He has taken particular interest in the Society's Annual Exhibition and has himself exhibited there in recent years—an experience which will be most helpful to him as the Chairman of the Exhibitions Committee.

Presentation of Charles Chree Medal and Prize

The Charles Chree Medal and Prize will be presented to Dr. Scott E. Forbush at a scientific meeting of the Institute and Society to be held in the Physics Department of Imperial College (Prince Consort Road, South Kensington, London, S.W.7) at 5 p.m. on Wednesday, May 3 next. After the presentation Dr. Forbush will give an address on " The equitorial electro-jet in Peru ". Tea will be served in the College at 4.15 p.m. No tickets are required for this meeting and visitors will be welcome.

Short Course for Teachers of Physics in Sixth Forms of Schools

The Physics Department of the University of Cambridge, in co-operation with the Institute and Society, has arranged a course for teachers of physics, to be held in the Cavendish Laboratory from Tuesday, 1st August, to Thursday, 3rd August, 1961. The number able to attend will be limited to seventy. Further particulars and application forms can be obtained on request from Dr. A. D. I. Nicol, A.Inst.P., Secretary to the Department of Physics, Cavendish Laboratory, Free School Lane, Cambridge ; the closing date for applications is April 29.

Noise in Electronic Devices

In October 1959 the Electronics Group held a short conference on " Noise in Electronic Devices ". The seven papers then presented are to be published at the end of this month by Chapman and Hall Ltd., on behalf of the Institute and Society. The retail price is 35s. Members, Students and Subscribers may obtain one copy each, for their personal use, at the reduced price of 24s. Their orders, with remittances, should be sent to Headquarters.

Symposium on the Physics and Chemistry of High Pressures

A Symposium on The Physics and Chemistry of High Pressures sponsored by The Society of Chemical Industry, The Institution of Chemical Engineers and The Institute of Physics and The Physical Society is to be held on June 26-28, 1962, in London, during the 3rd Congress of the European Federation of Chemical Engineering. This international Symposium is to be held to mark the retirement of Professor D. M. Newitt from the Courtauld Chair of Chemical Engineering at Imperial College. It will cover theoretical, experimental and applied work on high pressures (that is, on pressures from about 1000 atm. upwards). The subjects to be discussed include changes of phase, the study of optical, electrical and other physical properties, the equilibria and rates of chemical reactions, and work on new techniques, equipment and design. Work on transient properties, such as explosive and shock-waves will not be discussed. Those interested in submitting papers or in participation are invited to write to the Secretary of the Society of Chemical Industry or to Professor J. S. Rowlinson, Department of Chemical Engineering and Chemical Technology, Imperial College, South Kensington, London, S.W.7.

The Development of Fluid Fuel Reactors

Dr. Alvin M. Weinberg (Oak Ridge National Laboratory) will present a paper on the Development of Fluid Fuel Reactors at a meeting of The Institution of Chemical Engineers on April 24, 1961. This meeting is to be held under the auspices of the British Nuclear Energy Conference, and will take place at the Federation of British Industries, Tothill Street, London, S.W.1. It will begin at 5.30 p.m. (Tea at 5 p.m.)

International Conference on Ionization Phenomena in Gases

The 5th International Conference on Ionization Phenomena in Gases sponsored by the Association of the German Physical Societies (Plasma and Discharge Physics Group) will be held at Munich from August 28 until September 1, 1961. Application forms and information are obtainable from the Conference Office (Postfach 463, Munich). Pre-prints will be sent to members of the Conference on or about July 1, 1961.

Symposium on Molecular Structure and Spectroscopy

The Symposium on Molecular Structure and Spectroscopy will be held at the Department of Physics and Astronomy, The Ohio State University, this year from June 12 to June 16, 1961. There will be discussions of the interpretation of molecular spectroscopic data as well as methods for obtaining such data. In addition, there will be sessions devoted to those phases of spectroscopy of current interest. For further information, or for a copy of the program when it becomes available, write to Professor R. A. Oetjen, Department of Physics and Astronomy, The Ohio State University, Columbus 10, Ohio.

Radioactive Hazards in Industry: Draft Code for Protection of Workers

Requirements for the protection of workers against ionizing radiations and other hazards from radioactive substances are laid down in a statutory draft of Regulations published by the Ministry of Labour on March 30, 1961.

The Ionizing Radiations (Sealed Sources) Regulations, 1961, are published in accordance with Section 129 of the Factories Act, 1937. The second preliminary draft of these Regulations (then entitled the Factories (Ionizing Radiations) Special Regulations) published in January 1960 included a general invitation to make comments on the proposed Regulations.

The text now published has been prepared in the light of the observations received and of consultations held with various organizations.

The Regulations lay down maximum permissible radiation doses which may be received by employed persons. Any objection to the proposed Regulations by or on behalf of the persons affected should be sent to the Minister of Labour, 8 St. James's Square, S.W.1, by June 9, 1961. Copies of the new document are on sale at H.M. Stationery Office, price 9d.

Reviews of Books

THE COMPLETE SCIENTIST

Report of the Leverhulme Study Group to the British Association for the Advancement of Science

London : Oxford University Press. Pp. xxiii + 162. Price: Cloth 18s.; Paper 12s. 6d.

At a time when science is expanding its boundaries at a continually increasing rate, and when its influence on society is widening, the problems of providing a broader education for scientist and non-scientist alike are considerable. For the future scientist and technologist there are special pedagogic problems which relate not merely to the teaching of science, important as that may be, but also to the content of the non-scientific courses which might be deemed to be necessary, and the way these are taught and examined, both in schools and universities.

The Leverhulme Study Group formed in 1958 by the British Association, with Sir Patrick Linstead as Chairman and Director, " to report on the desirability of broadening the education of those intending to become professional scientists and technologists " have now published the results of their enquiry. Two small surveys of boys', girls' and mixed schools in England and Wales were made ; information was collected from thirteen university bodies, and about thirty witnesses, some of them drawn from industry and the professional institutions, gave evidence. The enquiry was not extended to include scientists and technologists in sandwich courses in colleges of technology. The report is a useful collation of facts and opinions, which will not greatly startle many engaged at one stage or another in education, but it is to be hoped it may stir teachers and administrators to make some of the changes proposed.

The Group is satisfied that school education up to O level of the general certificate of education examination is reasonably broad, but it suggests that in the sixth form too much time is devoted to mathematics and science. It finds that about two-thirds of the total average time-table is devoted to mathematics and science lessons or practicals ; in addition sixth formers spend some time on study periods and on preparation out of school so that about 30 hours a week or more are consumed on specialist studies. On the other hand all non-scientific subjects are crammed into five to seven periods a week. It is suggested that this must be increased to ten or twelve periods a week if the non-scientific subjects, even when taught by good teachers, are to make the impact they should. How is the time to be found ? Not by providing three years in the sixth form for all pupils, although some would profit from such an arrangement. A reduction in the time spent on science and mathematics is inevitable ; syllabuses will have to be re-cast (and there are movements in this direction already) and teaching methods re-thought and re-fashioned. One cannot help speculating in what ways American experience with Physical Science Study Committee courses might help.

Turning to the universities and how they might build on the foundations which should be laid in the schools, the report surveys what is being done in thirteen universities or colleges of a broadly representative character. The information relates to the provision of courses or lectures on non-scientific subjects, either within or without the curriculum, for mathematicians, physicists, chemists, those following courses in general science, and electrical and mechanical engineers. Not only is the provision meagre, but where the courses are optional only a small minority of the students attend. In physics more attention is given to non-scientific subjects than in some other honours courses, but of the fourteen courses examined one made no provision, two offered only optional subjects, and the others included some compulsory subjects in the first year only.

"At Cambridge a compulsory essay paper was included in the Part II examination but no intra-curricular provision was made for it. Elsewhere, whether compulsory or not, the intra-curricular time estimated to be given to these subjects in lectures and classes was, again, two or three hours a week. The subjects were confined to the first year, except at Leeds, where they continued into the second ". On the other hand, the time devoted to the specialist subjects in lectures, classes and laboratory work amounted to about 20 hours a week over the whole course. Keele, with its interesting experiment of a foundation year, stands out in contrast to all this.

The non-scientific subjects studied include a language (often for technical reasons), occasionally economics and rarely fine art ; the history and philosophy of science occurs more often in optional courses. There is little attention given to English, except in some courses for engineers and some essay-writing, and hardly any time devoted to the social sciences which one would have thought were of great importance to both scientists and engineers. Some argue understandably that formal lectures of this kind are of little importance, and place a greater emphasis on the general educative influences which university life, particularly when students are in residence, should and does provide. Again, there are influences outside the university ; it has been claimed that students in London have unique opportunities " when one considers that they are free to attend any and all of the special lectures provided for them as well as all the other cultural opportunities of a great metropolis ", but all this does not dispose of the need for specific provision within the colleges. Experience with courses in general studies in colleges of technology underlines this need.

The Report includes some figures for Birmingham University which show that the total weekly time-load of students reading for a first degree in science or engineering is between 35 or 40 hours for specialist subjects alone, including about 20 hours per week on " informal " work done in the students' own time. The Group concludes that this is not only too heavy for the " middling " man, but allows too little time for those elements of university life wherein its main value lies.

What then should the universities do ? Overhaul their teaching methods, modernise their syllabuses,

appoint more tutors and make more use of tutorials, provide alternative general courses, extend their teaching terms—all these are referred to, but more attention is devoted to the possible extension of honours courses to four years, which, however desirable educationally, is ruled out over the next decade on practical grounds. It would demand additional staff and more buildings at a time when it will be difficult enough to provide the increased number of places already planned. Such a reform is, therefore, relegated to the future ; meanwhile the universities can set about the revision of syllabuses and teaching methods and plan for 1975, and for the next fifteen years at least the grammar schools must continue to bear the main responsibility for the foundations of a broader education. We are back to the traditional pattern of the relationships between schools and universities.

If the schools are to be helped to carry out the recommendations concerning the reduction of time spent on science and mathematics in the sixth forms, there are several problems that must be solved. Some of these—university entrance procedure, undue pressure on university places and quality in teaching in schools—are discussed in the third and final chapter of the Report. Some modifications of the advanced level examinations and of university entrance examinations and requirements are proposed, in keeping with those made by other groups and committees.

As to pressure on university places, it is suggested that already excessive as this is " it will get worse and is most unlikely to improve for at least 15 years unless present policies are revised. Such a revision would include reassessment of the part to be played in higher education not only by the universities but also, for example, by the colleges of advanced technology ". We can only hope that the Robbins Committee which has recently been appointed will help us to see a way out. Finally, the need for science teachers of the right calibre is again stressed; it is right to say that if the country " wants more graduate scientists and engineers, and if it wants them to be soundly educated, to be broadly educated, the country must will the means to this end ; it must put first things first ", but what does it avail ?

J. Topping.

PHYSICS OF SEMICONDUCTORS

By A. F. Ioffe

London : Cleaver-Hume Press Ltd. Pp. xi + 436. Price 84s.

The volume has previously been available in this country in the original Russian edition (1957) and in German translation (1959). The recently-published English edition is an excellent introductory general text on semiconductors, written by the man who for nearly forty years was the driving force behind work on semiconductors in the Soviet Union and who died at the age of eighty during the autumn of 1960. The reviewer was fortunate to meet Professor Ioffe in Prague shortly before his death and to hear his expositions, both in public and private, on the basic concepts of semiconductors and of the difficulties which still face us, such as the explanation of the temperature variation of carrier mobility. Ioffe had the simplicity of manner associated with great men and his book, while dealing with fairly difficult material, maintains a simplicity of exposition which conceals a mastery of the subject. There are seven chapters on solid electrolytes, metals, electronic semiconductors—a general survey, fundamentals of the quantum theory of semiconductors, physical phenomena in semiconductors, methods of measuring basic properties, and semiconducting materials. The book ends with several pages of " Conclusions " which summarize the successes of the theory of semiconductors but which indicate the difficulties and deficiencies. One conclusion is that it is too simple to carry over the concepts of the band theory of metals to semiconductors and that a new approach is required. Another idea which recurs throughout the book is that the properties of semiconductors are determined largely by short-range order.

The approach to the subject of semiconductors is rather different in outlook from what one finds in some Western texts, and although band concepts are used widely, many topics are treated from the Heitler-London approach. There is rather more emphasis on semiconductors having ionic bonds, on amorphous solids and on liquids, than one finds in introductory Western texts. Compared with the successful introductory text by R. A. Smith, the standard of exposition is similar, although Dr. Smith's book is more mathematical and costs rather less. The English style is remarkably good in translation and the book may be very safely left in the hands of undergraduate students. Semiconductor specialists could probably gain from a reading of the book and for the solid state electronic engineer, the book would provide a fuller and in some ways more rigorous non-mathematical background to the subject than is usually found in engineering texts.

C. A. Hogarth.

MECHANICS. Volume I of Course of Theoretical Physics

By L. D. Landau and E. M. Lifshitz. Translated from the Russian by J. B. Sykes and J. S. Bell

Oxford : Pergamon Press Ltd. Pp. vii + 165. Price 40s.

All nine volumes comprising the *Course of Theoretical Physics* by Landau and Lifshitz are being translated into English. Five have already been published and reviewers have referred to them as excellent and readable volumes in which comprehensive treatments are presented with commendable clarity. The present reviewer sees no reason why *Mechanics* should not be equally well received. This volume is concerned with classically Newtonian mechanics. Starting from Galileo's principle of relativity and Hamilton's principle of least action, the authors develop a logical treatment of the equations of motion, the laws of conservation, collisions between particles and the motion of a rigid body. The final chapter deals with Hamilton's equations. There is a good selection of problems for the reader to attempt.

This is an advanced treatment which will be much appreciated by mathematicians and theoretical physicists. The translation is good and the standard of production is very high.

J. Crank.

PRACTICAL NUCLEONICS. A course of experiments in nuclear physics

By F. J. Pearson and R. R. Osborne

London: E. & F. N. Spon Limited. Pp. xvi+208. Price 37s. 6d.

Laboratory courses on atomics and nucleonics are increasing in number—courses for engineers, for metallurgists, for technologists, for chemists taking subsidiary physics, and even for physicists—and the publication of Pearson and Osborne's book is most timely. Based on the authors' successful courses in the Birmingham College of Advanced Technology, it should be useful both to those about to set up similar courses elsewhere, and to all of us who run advanced practical courses in physics.

The introductory chapter explains the aims and scope of the course, and provides an insight into the authors' philosophy of student laboratory work. Their proposition that " . . . it is the production of numerical results (to be compared with other predetermined values) which gives most satisfaction to the student and, incidentally, allows the demonstrator more easily and accurately to assess his ability " will strike a response, rich in overtones or undertones, from the book's more experienced readers; and there are wise remarks about the need to train students to react constructively to results which disappoint their uncritical optimism. This chapter includes a brief account of error theory and the statistics of counter experiments; this is quite neatly done, but it is indefensible to describe the standard deviation as " the most likely error " in an observation.

The succeeding chapters give detailed descriptions of 49 experiments covering determinations of a number of physical constants (e, e/m, h and c), the operation of certain valve and transistor circuits, the use of electroscopes, Geiger counters, scintillation spectrometers, nuclear emulsions and various neutron detectors, the study of natural and induced radio-activity, the calibration of sources, and neutron diffusion. One useful feature of many of the suggested experimental procedures is the systematic approach to the analysis of data obtained in situations of some complexity—complexity which may arise from the random nature of the phenomena, or from the simultaneous presence of a number of processes which have to be separated out. This is an important aspect of experimentation, which it is all too easy to avoid when designing student experiments. Another pitfall which the authors avoid with considerable skill is the mystery of the " black box ": they see to it that the student learns the properties and limitations of the instruments he is given before he has to interpret their " pointer readings ". It is a pity that the concluding chapter on " Electronics " is so much weaker than the rest. Perhaps it was felt that information about suitable valves, transistors and component values would be available in departments teaching at this level, but many will feel a lack of consistency in the detailing of the electronics experiments, and it is symptomatic of this that not all the circuit symbols which appear in the text can be found on the diagram to which they refer.

Much of the book is clearly addressed to laboratory organizers and staff; on the other hand the " Experimental Procedure " sections are written as instructions to the student, and there the appearance of occasional asides to the supervisor strikes an odd note which could have been avoided by slight rearrangement of the material. A few photographs of apparatus are included: these show apparatus set out as for a display, but the explanatory tickets are not always legible and the result is not particularly informative. The writing is lucid and direct, and the indexing is good, different type faces being used to distinguish between references to the glossary, to the general text, and the descriptions of experiments.

To sum up: this is an extremely useful book; one wishes the publishers had been optimistic enough to set the price lower.

R. M. Sillitto.

DICTIONARY OF ELECTRONICS

By Harley Carter

London: George Newnes Ltd. Pp. vi+377. Price 35s.

It is difficult to conceive who are the potential users of a scientific dictionary such as this compilation on electronics. It defines many standard terms and some jargon. Some random tests indicate that, on the whole, the information is correct though sometimes almost fatuous. (*Loft aerial:* A receiving aerial suitable for erection in the loft of a house, and in particular a television aerial of this type. . . .). It must be difficult for the compiler to make his selection, but in this case it seems to be somewhat arbitrary. The following subjects are omitted: avalanche transistor, Cerenkov radiation, characteristic impedance, critical coupling, cut-off frequency, Ezaki diode, giga, impurity semiconductor, p-n junction. A parallel list of inclusions is: tunnel diode, K-shell, lecher wires, coefficient of coupling, band-pass filter, Lodge valve, milli, mega and kilo, thoriated filament, coherer.

At a cost of 35s. for 377 octavo pages this is very poor value for money. It is not likely to appeal to physicists or electrical engineers.

M. R. Gavin.

THE FABRIC OF THE HEAVENS

By Stephen Toulmin and June Goodfield

London: Hutchinson and Company Ltd. Pp. 272. Price 25s.

This is the first of a planned series of volumes under the general title of " The Ancestry of Science ". It deals essentially with problems of astronomy and dynamics, and the treatment is broadly historical. In 1957, the authors started a course in the University of Leeds entitled *Origins of Modern Science*. The book before us is the result, or at least part of the result. There can be no reasonable doubt that instruction of this kind is both needed and appreciated, and that it helps to bridge the gap between scientific and humanistic studies. The great difficulty is that the one effective method of ensuring a firm grasp of principles is denied to the authors, namely the assurance that their readers (or hearers) possessed an adequate knowledge of mathematics. The discussion is almost wholly devoid of such a discipline; and is a good example of what can be done with this severe limitation. Even so, some sentences

show an irritating colloquialism, which is quite needless, and which detracts preceptibly from an otherwise very pleasant book.

The discussion follows the inevitable chronological sequence, Babylonia, Greece, Europe in the middle ages, the Newtonian period, and so on. An excellent feature is the authors' emphasis upon the positive nature of the contributions made by the early scientists: they did not intend what we envisage by velocity, force, and various other dynamical conceptions. Consequently, it is as stupid as it is unjust to read our twentieth-century thoughts into their expressions. There has been too much unintelligent criticism of historical natural philosophy. Much past labour doubtless has little more than antiquarian interest. But the grand point is that all this shows the evolution of thought in men's minds, and should prevent us from assuming that we have said anything approaching the last word on these wide issues ourselves.

The bibliographies are somewhat restricted and a little unimaginative. There are several recent works on Anaxagoras and Bruno the Nolan of a non-mathematical nature, which might well have been included. No index is provided, but the table of contents is well sub-divided, which goes some way to repair this omission.

F. I. G. Rawlins.

THE CHALLENGE OF FUSION

By Duncan Curry and Bertram R. Newman

Princeton and London: D. Van Nostrand Company, Ltd. Pp. xi+192. Price 41s. 6d.

This book had its origin in a research project undertaken during the session 1957-8 by two students at the Harvard Graduate School of Business Administration. About one-third of the text is devoted to an elementary explanation of thermonuclear reactions and experimental devices for achieving fusion. The style of writing is clear but the discussion is conducted at a very simple level.

The rest of the book is a naively optimistic analysis of the impact of fusion on industry and society. The authors make two assumptions. First, they believe that the large-scale generation of electrical energy from thermonuclear reactors will be accomplished during the next decade. Secondly, they believe that the cost of power will be substantially lower from fusion than from coal, oil or fission. Cheap power, they assert, will make possible irrigation of deserts, space travel, anti-gravity, climate control and radio-powered motor cars.

The advent of nuclear energy, whether from fusion or fission, certainly raises intriguing possibilities for industrial development ; an able study of these matters was made as long ago as 1950 (*Economic aspects of atomic power*, by Sam H. Schurr and Jacob Marschak : Princeton University Press). *The challenge of fusion* is a lightweight essay, good enough no doubt for its original purpose but scarcely deserving publication in the ponderous form now before us.

J. M. A. Lenihan.

RIVAL THEORIES OF COSMOLOGY.

A Symposium and Discussion of Modern Theories of the Structure of the Universe

By H. Bondi, W. B. Bonnor, R. A. Lyttleton and G. J. Whitrow.

London: Oxford University Press. Pp. xii+64. Price 9s. 6d.

It was an excellent idea to issue in a small book these broadcast talks on cosmology, and the subsequent debate which summarized the contributions of Bondi, Bonnor, and Lyttleton under the chairmanship of Whitrow. Although clearer than most lectures on such topics, they made difficult listening when so many statements called for " Stop and say that again slowly". Of the solutions of the " red-shift " in extra-galactic spectra here mentioned, the most unfamiliar will be that very recently due to Bondi and Lyttleton: it invokes simply a possibility very congenial to the experimental physicist. The suggestion is that if proton and electron differed in charge (usually supposed equal) by so much as one part in 10^{18}, a hydrogen cloud of cosmic size would scatter electrostatically in the " expanding universe " manner suggested by the red-shifts.

Bondi in discussion always confesses very honestly and refreshingly his standpoint as to the possibility of scientific knowledge, and he escapes thereby the vague uneasiness with which most cosmologists are regarded by the working physicist. But the whole set of talks in this book are pleasantly free from the vice of " It is known with absolute certainty that . . . " which has lowered the reputation of some cosmology. The little book is also enlivened by some good photographs, modern even to the recent tendency to become rather disillusioned over " colliding galaxies ".

Martin Johnson.

EXPERIMENTAL PHYSICS FOR COLLEGES

By Walter A. Schneider and Lloyd B. Ham

New York and London: The Macmillan Company. Pp. xiv+442. Price 34s. 6d.

Described as " Experimental Physics for Colleges " this book would in fact be suitable for English sixth forms. The first edition appeared in 1932; it has been revised since, but the impression remaining is still that of the thirties rather than the sixties. It is sound, thorough, beautifully printed on good paper, and is entirely conventional. Do not look here if you wish to find the latest American ideas on experimental physics. The preface to the revised edition says " . . . many new experiments . . . that have gradually assumed greater importance, as in Experiments 25, 45, 47; "—one turns these up in the hopes of finding some new experiment on, say, electronic charge, or radioactive half-life, or the determination of G, but no; 45 is a.c. and impedance, 47 is triode characteristics, and 25, believe it or not, is coefficient of linear expansion.

Similar books printed in this country are available more cheaply; nevertheless a copy might advantageously be purchased for the laboratory bookshelf. One advan-

tage has not been mentioned: the electrical section uses all three systems of units, C.G.S., M.K.S. rationalized, and M.K.S. unrationalized.

H. F. Boulind.

SCIENCE: CHEMISTRY, PHYSICS, ASTRONOMY

The MacDonald Illustrated Library

Editorial Board: J. Bronowski with Sir Gerald Barry, James Fisher and Sir Julian Huxley.

London: MacDonald & Co. Ltd. Pp. 367. Price 45s.

Any publication which presents scientific information to laymen, lucidly, accurately and intelligibly, is to be welcomed. To-day many books attempt more than this—they aim to reveal science as an exciting human activity with many social implications. Their success depends upon several things. The quality and lavishness of the illustrations are important. It is well to have a panel of distinguished scientists associated with the publication. The text must not be too difficult. Let it be stated immediately that the book under review, the first of a series, is a distinguished addition to the growing list of publications designed to popularize science. It is beautifully and copiously illustrated; credit for which should presumably be given to Hans Fermi. The editorial board includes a number of very well-known scientists; some guarantee, presumably, that the information in this comprehensive survey of ancient and modern chemistry, physics and astronomy is accurate. The editorial director of Rathbone Books, James Fisher, however, states in his preface that in spite of the care taken to ensure accuracy, because of the rapid advance of science " no individual member of the editorial board could be responsible for *every* fact or opinion in these books ". A team of contributors is, in fact, responsible for the writing of the text. The series as a whole is intended to provide a " truly broad and international compendium of knowledge " which will appeal to " young people and their parents ".

Inevitable as this method of production might be, it has its drawbacks. It is costly, hence if the book is to be published at a reasonable price the number of copies printed must be very large and appeal to an international audience. The difficulties of making science understandable to a mass audience are obvious. There are also problems of achieving coherence and consistency in the volume as a whole. The intentions of the editorial board are clear. It is stated that the " pictures mean little without the text and the text means little without the pictures. But designed and woven as a whole the two together have more impact, value and economy of message than can be given in the pages of a conventional book ". Moreover it is claimed the " systematic method of presenting information " makes for " better teaching, better understanding and better logic than the alphabetic method ". An adequate solution to the problems of coherence and consistency and to the achievement of the stated aims of the board depends on the imposition, by the editor if necessary, of a consistently maintained theoretical framework. A number of criticisms which might be made of this book arise from lack of firm editorial direction. It might be that the editorial board took pains to work out, and agree upon, the epistemological and pedagogical theories on which the selection and organization of the material in the book were to be based. The critical reader is unlikely to think that they have been completely successful. There is considerable unevenness in the writing. Some sections seem to be intended for readers with a considerable knowledge of science: others for those with very little knowledge indeed. The methods of presenting data vary; in some cases descriptions of simple experiments initiate a topic; in other cases information is built up from a number of verbal definitions. It is not that the logics behind the various methods of presentation are not clear but they do show rather fundamental differences.

Perhaps some explanation for the looseness of the logic might be found in the attempts made at the very end of the book to state what constitutes scientific method. The assumption that there is *one* scientific method which can be clearly stated seems somewhat dangerous. There might in fact be several and it might be well to regard all of them as useful in their way but in no way as representing the truth. There is also in this section what appears to be a curious failure on the part of the author to distinguish between the classical method of induction as described, for example, in the early part of J. S. Mill's *System of Logic* and the inverse deductive method (which seems to correspond rather closely to the hypothetico-deductive method) which he discusses later particularly with regard to the social sciences. Although there appear to be rather significant differences between these two approaches—and philosophers of science seem now to favour the hypothetico-deductive method—the author seems to regard them as synonymous.

A few minor objections might be made to the layout of the book. The divisions between the chapters and sections are not very clear and since they do not, in spite of editorial claims, form part of a recognizably unified whole this failure might lead to some confusion. Some of the definitions too have an archaic pedagogical flavour. Is it necessary to repeat the tautology that " mass is the quantity of matter in a body " when Newton's definition in terms of basic measuring instruments is available ?

In spite of these comments the volume is to be thoroughly recommended. Perhaps it does not quite measure up to the claims made for it by the editorial board but the illustrations are aesthetically superb and the text is very much better than in some books of this kind. It will be read with pleasure and profit by many intelligent young people and glanced at by a great many busy adults. Moreover it does present a very real challenge to the producers of school textbooks. It is to be hoped that in the not too distant future this challenge will be met.

Brian Holmes.

SELECTED PAPERS ON STRESS ANALYSIS

Presented at The Institute of Physics Stress Analysis Group Conference, Delft 1959

London: Chapman and Hall Ltd. New York: Reinhold Publishing Corporation. Pp. 114. Price 50s.

In April 1959 the Stress Analysis Group held a conference at Delft at the invitation of the Netherlands

Institut T.N.O. Eighteen of the papers presented at this conference are now published in their original languages (English, French or German) with summaries in all three languages. Among the topics covered are photoelastic methods for the measurement of stresses in shells and also for residual stresses and other stress systems in equilibrium, such as toughened glass. The use of these methods for measuring the stresses in a shaft with a transverse hole subjected to bending and also for the dynamic stresses set up by impact on notched and plain beams is described. Auxiliary equipment mentioned for use with electrical resistance strain gauges includes slip rings, means of multiple recording, a calibrator for high temperatures and apparatus for strain measurement in flight. Special strain gauges are described for use in high precision load cells. There are two new methods of measuring strain, one mechanical and one electrical, and two new applications of the Moiré method. The tape recording of data is discussed. The detailed examination of a welded connection between a beam and a column is another subject and there is a discussion on the brittle fracture of steel. Of the remaining papers, some have already been published whilst in others the physical aspect is subsidiary to wider interests. These papers have accordingly been summarized briefly and a list of authors' names and addresses is included.

Copies are available to all grades of the Institute and Society at the special price of fifteen shillings. Orders should be sent to Headquarters with remittances.

Forthcoming Institute and Society Meetings

Date	*Place*	*Speaker*	*Title and other details*	*Time*	*Branch or Group*
April 20 to 22	**Newcastle upon Tyne** King's College		**Conference on Palaeomagnetism** Registration is necessary		
April 21	**Birmingham** Students' Union, The University		Annual Branch Dinner	7.00 p.m. for 7.30 p.m.	Midland
April 21	**Aberystwyth** University College	Dr. G. R. Evans, Grad.Inst.P. (*University of Edinburgh*)	**European co-operation in nuclear research**	5.15 p.m.	South Wales
April 24 to 27	**Southampton** The University		Annual Conference on **The mechanism of rupture** Registration is necessary.		Stress Analysis
May 2	**London** The Royal Commonwealth Society	Sir John Cockcroft, O.M., F.R.S., F.Inst.P.	The first Anniversary of the establishment of the amalgamated body will be marked by a **Presidential Address** on **The development of physics** Admission by ticket obtainable from the Secretary of the Institute and Society.	5.00 p.m.	
	London Park Lane Hotel	**ANNUAL DINNER OF THE INSTITUTE AND SOCIETY**		7.30 p.m.	
May 3	**London** Imperial College	Dr. Scott E. Forbush (*Carnegie Institution, Washington*)	**Charles Chree Medal and Prize Presentation and Address on The equitorial electro-jet in Peru**	5.00 p.m.	
May 4	**London** Imperial College	Mr. E. W. H. Selwyn, F.Inst.P. (*Kodak Ltd., London*) Mr. K. H. Birch (*Imperial College*) and other contributors	**Spatial frequency response as a criterion of the performance of optical systems**	2.30 p.m.	Optical

Date	*Place*	*Speaker*	*Title and other details*	*Time*	*Branch or Group*
May 5	**London** Imperial College	Dr. Jurgen Tonndorf (*The State University of Iowa*)	**The analytic function of the cochlea according to studies of cochlear models**	5.30 p.m.	Acoustics
May 11	**Liverpool** The University	Professor J. M. Cassels, F.R.S. (*University of Liverpool*)	**Fundamental particles**	7.00 p.m.	Liverpool and North Wales
May 11	**London** B.B.C. Television Centre	Dr. D. Kleis (*Philips Electrical Ltd., Eindhoven*)	**Ambiophony**	5.30 p.m.	Acoustics
May 12	**London** Headquarters		Half-day symposium on **Internal friction measurements**	2.30 p.m.	Non-Destructive Testing
May 15	**London** Headquarters		Half-day symposium on **Recent advances in resistance strain gauge techniques** Registration is necessary	2.30 p.m.	Stress Analysis
May 17	**London** Headquarters	Mr. M. Zvegintzov (*National Research Development Corporation*)	Discussion meeting on **The future of deep low temperature engineering**	4.00 p.m.	Low Temperature
May 18	**Malvern** Royal Research Establishment		Visit to Royal Radar Research Establishment, followed by a talk Registration is necessary	2.00 p.m.	Midland
June 1	**London** Imperial College	Mr. K. Hacking (*B.B.C. Research Laboratories*)	**Secondary flare in lenses**	2.30 p.m.	Optical
June 8	**London** Imperial College		Symposium on **Medical acoustics**		Acoustics
June 9	**Oxford** Clarendon Laboratory		**Summer visit to the Low Temperature Department of the Clarendon Laboratory** Registration is necessary	11.00 a.m.	Low Temperature
June 16	**Manchester** Literary and Philosophical Society		All day meeting on **Spectroscopic studies using time resolution techniques** Registration is necessary	10.30 a.m.	Applied Spectroscopy
June 24	**London**		**Summer meeting and visit to Royal Naval College, Greenwich** Registration is necessary	11.00 a.m.	London and Home Counties
June 30	**Winfrith** Atomic Energy Establishment	Summer Meeting — Visit to Atomic Energy Establishment Registration is necessary			South Western
July 10 to 12	**Durham** The University		Symposium on **Thermoelectricity** Registration is necessary. Programs and application forms may be obtained from Professor D. A. Wright, F.Inst.P., Department of Applied Physics, Science Laboratories, South Road, Durham.		
July 10 to 14	**London** Imperial College		Conference on **Optical instruments and techniques** (arranged under the auspices of the International Commission for Optics by The British National Committee for Optics)		Optical
July 10 to 14	**Nottingham** The University		Annual Conference Registration is necessary.		Electron Microscopy
July 19	**Camden Town** and **Debden**		All day visit to Hilger & Watts Ltd. factories Registration is necessary.		Education

The Register

ELECTIONS TO MEMBERSHIP

THE FOLLOWING ELECTIONS WERE MADE BY THE COUNCIL ON MARCH 7, 1961

An asterisk (*) indicates transfer from another grade

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*Mawbey, Malcolm William Stanley, Assistant Experimental Officer, U.K. Atomic Energy Authority.

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FELLOWSHIP of The Physical Society (13)

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Tosswill, Christopher Haly, M.A., Research Physicist, Richardsons Westgarth, Berks.

Valadares, Manuel, D.Sc., Director of Research, L'Aimant-Permanent Laboratory, France.

Ninety-one Students and eleven Subscribers were also admitted.

Manuscripts accepted for publication in the Institute and Society's periodicals

British Journal of Applied Physics

Time lags in the electrical breakdown of glass immersed in water. By M. N. Azam and H. Dickinson.
When measuring the electric breakdown strength of cover glass immersed in deionized water, time-lags to breakdown were observed. The mean statistical time lag was (12 ± 1) μsec. The breakdown strength between spherical electrodes was found to be $(11{\cdot}4 \pm 1) \times 10^8$ v/cm.

Temperatures under steadily heated floors. By I. G. Donaldson.
The temperature distribution below the heated floor of a kiln has been investigated both theoretically and by model experiments. The aim is to determine how much insulation is required to keep the temperature of the ground below that point (perhaps as low as 40°c) at which it tends to dry out and subside. The results show that a considerable thickness of insulation is necessary to achieve this, but that much less insulation is needed if a thin layer of high conductivity is placed below the insulation. Iron reinforcing mesh could act as a high conductivity layer. It also appears that there is an advantage both in cost and in effectiveness in making the insulation thinner toward the sides of the kiln. The conclusions also apply to the insulation of the floor of cold storage rooms and skating rinks where the aim is to prevent 'frost heave'.

Electrode contamination and arc formation. By H. de B. Knight.
When the surface of the cathode of a gas discharge is contaminated with insulating substances or with mercury, the discharge may develop into an arc with a lower voltage drop than when the contaminant is not present. Insulation particles are added to the electrodes of spark-gaps designed to have a low impedance. With mercury, the minimum voltage and current values required for arc formation are lower the more effectively the mercury wets the electrode surface. Both contaminants play a part in the phenomenon of arc-back in arc rectifiers. The probability of arc-back depends on the random concentration of ions and also on the nature and extent of the contamination of the anode; this varies both with the conditions of operation and with previous treatment. The paper discusses the interpretation of tests made in 'synthetic' circuits to determine the probability of arc-back in a rectifier in service.

The end effects in a falling sphere viscometer. By A. D. Maude.
The calculation of Stimson and Jeffery of the force on two spheres moving coaxially through a very viscous liquid are extended to the case when the spheres move at different rates. This result is used to calculate the effect of the bottom of the vessel in a falling sphere viscometer and that of the upper surface of the liquid. Approximate solutions are also found in a form suitable for practical use.

Some visco-elastic properties of nylon. By F. L. Warburton, J. E. P. James and (Miss) S. Hother-Lushington.
The dynamic modulus of nylon fibres has been measured over a wide frequency range at different temperatures and humidities, and also the life under load. The measured life times were of the same order as the periods used in the dynamic experiments. The results of both sets of experiments can be explained on the assumption that increase in temperature only affects the internal friction of nylon whereas the absorption of water has also a significant although smaller effect on the elastic properties.

Journal of Scientific Instruments

Electrolytic tank for studying the flow of liquids through tubes of various cross sections. By M. J. Denton and S. G. Lipson.
Analogue methods of solving the Poisson equation in two dimensions are discussed briefly. The electrolytic tank equivalent must have a uniform current source density. An approximation to this is achieved by introducing equal currents through conductors spaced in a square lattice. As examples, the flow velocity distribution in a tube of rhombic cross section is shown, and the equivalent radii for rhombic tubes of various angles are found.

A nuclear resonance magnetic field stabilizer. By R. G. Eades, G. J. Jenks and A. Bradbury.
A nuclear resonance magnetic field stabilizer is described in detail. Circuit diagrams are included and the adjustment procedure is outlined for the particular application in which field fluctuations of one part in 10^8 have to be handled. An improvement by a factor of 100 in field stability is readily obtained.

A micro-tensile testing machine. By D. M. Marsh.
This paper describes a tensile testing machine for microscopic specimens. It can apply loads in the range from 1 mgf to 600 gf to specimens having cross-sectional areas down to 10^{-5} mm^2. Specimen extensions from a few ångstrom units to 15mm can be measured and, at constant temperature random errors in the extension measurement system are less than 5 Å (5×10^{-7}mm). The machine employs a torsion balance to apply the loads and a mirror-autocollimating telescope system to detect the extensions. Since it depends wholly on mechanical and optical principles it is practically drift free at constant temperature. It is adaptable for tests in special atmospheres, for autographic recording and for tensile testing of thin films.

An instrument to sharpen microtome knives. By A. L. Sims.
This instrument was designed to save the time spent in sharpening microtome knives by hand. It sharpens by simultaneous backwards and forwards and side to side movements of the knife over an abrasive plate. The movement is derived from an electric motor. The whole instrument is portable and requires no attention except to turn the knife over periodically. An adjustable steel toe allows the facet angle of the knife edge to be correctly set. This disposes of the dangerous operation of fitting to the knife the split cylindrical backing piece supplied by the knife-makers for this purpose. In order that the knife shall not be subjected to the stresses of clamping it is held in position on the abrasive surface by cylindrical permanent magnets, which also act in keeping the knife edge in contact with the abrasive surface with an even constant pressure. The use of magnets also facilitates the placing of the knife in its position for sharpening and its removal therefrom. It is shown that the repeated examination of the edge of the knife by microscope during sharpening is necessary.

A simple means of computing two-dimensional steady state heat flow in composite systems. By D. W. Stops.
Commercially available electrical conducting paper can be cut, punched or plied, to form geometrical shapes containing different resistances per square, to simulate analogues two-dimensional complexities which may be involved in potential flow. A method is described for redistributing the current in the analogue, to allow for temperature variations of thermal conductivities of materials in the actual heat flow system.

Fixed attenuators consisting of a network of identical resistors. By C. H. Vincent.
Fixed attenuators constructed of identical resistors have advantages of freedom from distortion by the stray self-inductance of the resistors and freedom from temperature changes. A suitable form for such attenuating networks is described. It is possible to design a network of this form to give attenuation in any ratio N to 1, where N is an integer. The minimum number of resistors needed for any value of N is not excessive, being less than 7 resistors per decade of N. A table is given which makes the calculation of an optimum network very easy for any value of N up to 400.

April 1961

Proceedings of The Physical Society

Magnetic anisotropy in single-crystal nickel films. By J. C. Anderson.

Single-crystal thin films of nickel, in the thickness range 50–500 Å have been prepared, by epitaxial growth on rock-salt, and their magnetic anisotropy measured.

All films show a uniaxial anisotropy superposed on the normal cubic anisotropy. In the discontinuous films, annealing in vacuum reduces the uniaxial component whilst in continuous films annealing increases it. Films grown in a vacuum of 10^{-7}mm are found to have few imperfections visible in the electron microscope and give more consistent results. The uniaxial component of anisotropy is shown to be a function of thickness, and is affected by the degree of vacuum achieved during deposition. It is suggested that the mechanism of directional ordering of oxygen atoms in the metal lattice, as proposed by Heidenreich *et al.* in 1959, would account for the results.

The scattering of low-energy ortho-positronium by hydrogen atoms. By P. A. Fraser and H. S. W. Massey.

When ortho-positronium collides with a hydrogen atom not only may it be scattered, but there is also the possibility of conversion of the ortho-positronium to para-positronium by electron exchange. The total elastic cross section and the conversion cross section have been calculated for positronium kinetic energies 0 to 9·8 ev, for the $l=0$ partial wave only. A particular choice of trial wave function explicitly satisfying the Pauli principle and a variational argument lead to integro-differential equations, with no 'ordinary force', from which the phase shifts have been obtained by a numerical method. The cross sections are very strongly energy dependent: the total cross section ranges from $15\pi a_0^2$ at zero energy to $2{\cdot}92\pi a_0^2$ at 6·8 ev, while the (conversion)/(total) ratio ranges from 0·176 to 0·070 over these energies. These ratios are well below the value 1/4 expected at high energies from the Born approximation. The total cross section results of Massey and Mohr for this problem using Born approximation were $230\pi a_0^2$ at zero energy and $25\pi a_0^2$ at 6·8 ev, with the (conversion)/(total) ratio 1/4.

Determination of the effective ionic charge of gallium arsenide from direct measurements of the dielectric constant. By K. G. Hambleton, C. Hilsum and B. R. Holeman.

Direct measurements of static and optical dielectric constants have been made on GaAs with a resistivity of 10^4 ohm cm at room temperature. Values obtained were $\epsilon_s = 12{\cdot}5(3)$ and $\epsilon_\infty = 10{\cdot}90$. An effective ionic charge, e_s^* of 0·46e can be deduced from these values.

Pre-breakdown ionization in hydrogen at low pressures. By S. C. Haydon and A. G. Robertson.

Detailed studies of pre-breakdown ionization in hydrogen gas at low pressures have been made in the presence of uniform electric fields and appropriate analytical methods and experimental procedures suitable for similar studies in crossed electric and magnetic fields have been established. The Lloyd-Loeb determinations of the first Townsend ionization coefficient α/p_0 from pre-breakdown ionization measurements are discussed and an observed pressure dependence of α/p_0 at $E/p_0 = 350$ is shown to be due to the presence of vapour impurities which can give rise to the large values of α/p_0 recently reported. Values of α/p_0 have been measured for the range of values of E/p_0 from 50 to 450 v cm^{-1} mm^{-1} Hg.

Collision broadening in the argon spectrum. By W. R. Hindmarsh and K. A. Thomas.

High resolution photographs of the near infra-red spectrum of an argon discharge at various pressures revealed that lines whose lower levels are connected by resonance transitions to the ground state suffered markedly greater collision broadening than those whose lower levels are metastable. The excessive broadening of the former group of lines is believed to be due to resonance collision broadening of their lower levels. The collision broadening of one line from each group, namely $1s_5 - 2p_9$ 8826·4 Å and $1s_4 - 2p_8$ 8696·5 Å, was measured. The half intensity collision width of 8826·4 was $14{\cdot}7 \pm 1{\cdot}0 \times 10^{-16}$ cm^{-1} per atom per cubic centimetre of argon, while that of 8696·5 was $2{\cdot}0 \pm 0{\cdot}3 \times 10^{-16}$ cm^{-1} per atom per cubic centimetre of argon. The ratio of collision width to collision shift (the latter being taken from the value reported by Hindmarsh and Thomas in 1959) was $-3{\cdot}1 \pm 0{\cdot}8$. This is in agreement with the value 2·75 predicted by the Lindholm theory for interaction due to van der Waals forces between the atoms. The resonance broadening of 8826·4 is related to the f-value of the argon resonance line $1p_0 - 1s_4$, 1048, and this is found to be $f = 0{\cdot}13 \pm 0{\cdot}03$.

A study of the $(^3He,d)$ reactions leading to ^{11}C and ^{13}C. By S. Hinds and R. Middleton.

The reactions $^{10}B(^3He,d)^{11}C$ and $^{11}B(^3He,d)^{13}C$ have been studied, using magnetic analysis, at a bombarding energy of 9·04 mev. A new level in ^{13}C at $6{\cdot}345 \pm 0{\cdot}010$ mev excitation was observed. Deuteron angular distributions leading to the ground and first five excited states of ^{11}C were measured and an attempt has been made to fit these with stripping curves. Absolute proton reduced widths for the ^{11}C levels have been extracted. Using the $^{11}B(^3He,d)$ reaction the energy levels of ^{13}C between 9 and 15 mev have been studied. Natural widths of levels at 10·84, 11·82 and 13·38 mev were measured to be 320, 300 and 700 kev respectively. Stripping analyses of the deuteron angular distributions yielded l-values of 2, 0, 0 and 1 respectively for the states of ^{13}C at 9·63, 10·84, 11·82 and 12·70 mev. Absolute proton reduced widths and also α-particle reduced widths, from the measured total widths, have been extracted for some levels of ^{13}C.

Some properties of resonance line-shape functions. By D. G. Hughes and D. K. C. MacDonald.

Some relationships involving line-width and second moment of broadened resonance lines are investigated.

It is of particular interest to determine how the properties such as line-shape of a multiply-broadened line depend on the properties of the individual lines. In certain cases the shape of the broadened line is the same as that of the individual lines, and particular attention is paid to this class of 'self-folding' functions.

Orbital electron capture ratio and beta spectrum of ^{204}Tl. By B. R. Joshi.

A direct measurement of the L/K electron capture ratio has been made for ^{204}Tl. An improved internal source scintillation counter technique was used. A crystal was grown containing ^{204}Tl and this crystal was totally enclosed in a well-type crystal. The experimental value obtained for this unique first forbidden transition ($\Delta J = 2$, yes) is $0{\cdot}42 \pm 0{\cdot}05$. This value may be compared with the value $0{\cdot}52 \pm 0{\cdot}05$ calculated from the electron capture transition energy.

In addition, information has been obtained on the β^- decay branch. The low energy end of the Fermi–Kurie plot of the β^- spectrum, after applying an exact shape correction factor, deviates slightly downwards from a straight line. This deviation is in the opposite sense from that obtained by previous workers with magnetic spectrometers.

The band spectrum of CuAg molecule in the visible region. By K. C. Joshi and K. Majumdar.

The emission spectrum of CuAg molecule in the visible region has been investigated in thermal emission at 1800°C in a vacuum graphite furnace. Bands have been observed in the region 4404090–3790. All these bands are degraded to red and have been classified in one band system as described as $A\text{–}X$. Bands can be represented by the equation :

$$\nu_{v'v''} = 25851{\cdot}6 + 178{\cdot}5\,(v'+\tfrac{1}{2}) - 0{\cdot}50\,(v'+\tfrac{1}{2})^2 - 231{\cdot}8\,(v''+\tfrac{1}{2}) + 0{\cdot}80\,(v''+\tfrac{1}{2})^2.$$

MgH and MgD bands at 2819Å and 2702Å. By M. Aslam Khan.

During an investigation of the spectra of metallic hydrides of group II of the periodic table, five new bands in MgH at 4428819, 2702, 2172, 2100 and 2088, a band system in ZnH at 2426Å and a band system in CdH at 2483Å have been observed and analyzed. Also the corresponding deuteride bands, where possible, have been observed. Only the MgH and the corresponding MgD bands at 2819Å and 2702Å are dealt with in this paper. They are classified as $^2\Sigma \rightarrow X\,^2\Sigma$ and $^2\Sigma \rightarrow X\,^2\Sigma$, transitions respectively. The rotational constants are calculated as follows:

MgH

$^2\Sigma \rightarrow X\,^2\Sigma$ (o, o) band at 2819Å { $B'_v = 6{\cdot}08\text{cm}^{-1}$, $D'_v = 3{\cdot}31 \times 10^{-4}\text{cm}^{-1}$; $B''_v = 5{\cdot}73\text{cm}^{-1}$, $D''_v = 3{\cdot}43 \times 10^{-4}\text{cm}^{-1}$; $\nu_e = 35550{\cdot}6\text{cm}^{-1}$

$^2\Sigma \rightarrow X\,^2\Sigma$ (o, o) band at 2702Å { $B'_v = 5{\cdot}78\text{cm}^{-1}$, $D'_v = 4{\cdot}0 \times 10^{-4}\text{cm}^{-1}$; $B''_v = 5{\cdot}73\text{cm}^{-1}$, $D''_v = 3{\cdot}63 \times 10^{-4}\text{cm}^{-1}$; $\nu_e = 36995{\cdot}4\text{cm}^{-1}$

MgD

$^2\Sigma \rightarrow X\,^2\Sigma$ (o, o) band at 2816Å { $B'_v = 3{\cdot}20\text{cm}^{-1}$, $B''_v = 2{\cdot}80\text{cm}^{-1}$; $\nu_e = 35548{\cdot}9\text{cm}^{-1}$

Micro-disk patterns on diamond dodecahedra. By D. C. Pandeya and S. Tolansky.

An account is given of microscopic and interference studies on the appearance of slightly raised disk formations on dodecahedral faces of various diamonds. More than a thousand such discs appear on one small diamond. The disks are shown to be slight elevations. It is conjectured that they owe their origin to a protective action of small bubbles. Evidence is given that solution or etch has taken place in the final stages of the crystal formation. The suggested micro-bubbles would locally prevent dissolution, leaving slightly raised disks. By postulating the possibility of slight movement or oscillation of the conjectured bubbles most of the observed topographical features of the disks can be accounted for.

Line shapes in the method of intersecting energy levels. By B. P. Kibble and G. W. Series.

The first part of this work is a study of the changes of intensity of the resonance fluorescence from mercury vapour as a small magnetic field H is applied, either parallel, or anti-parallel, to the direction of the incident light. The changes follow either a Lorentzian or a dispersion-type function of the Zeeman splitting of the excited state, according to the orientations of polarizer and analyzer in the beams of light.

In an experiment with an additional oscillatory field at a frequency ω_0, similar curves are observed in the region $H = H_0/2$. (H_0 is the field for which ω_0 is the Larmor frequency).

The observations are relevant to a recently developed technique in which intensity changes of this sort are used to make precision measurements in spectroscopy. The Lorentzian line shape is usually observed. The possibility of obtaining line profiles of other shapes was pointed out by Franken.

The estimation of domain wall velocity in a 'square loop' ferrite, and some observations on the reversal process. By J. E. Knowles.

Bitter pattern observations were used to investigate the relationship between the applied field and wall velocity in a polycrystalline manganese–magnesium ferrite. The wall velocity was found to lie in the range 500 to 1000 cm^{-1} sec^{-1} (effective) / 1 Oe, and the motion of the wall was shown to be impeded by Néel spike domain structures around pores in the material. The quasi-static nucleation and reversal process was also investigated : it was found that nuclei of reverse magnetization appeared on pores on the grain boundary, which evolved into trapezoidal domain structures.

The tensile strength of liquids in Berthelot tubes. By G. M. Lewis.

Experiments are described in which Berthelot tubes containing water are used in an attempt to estimate the maximum tension that can be sustained by a water–glass system under static conditions. The Berthelot tube is sealed at both ends and is almost completely filled with the liquid under investigation. On heating the tube the liquid expands until it completely fills the tube, but when it is subsequently allowed to cool the adhesion of the liquid to the walls of the tube prevents the liquid from contracting at a greater rate than the internal volume of the tube. Consequently a pro-

gressively increasing tension is set up in the liquid until it eventually ruptures. The tension in the liquid immediately prior to the instant of rupture is measured by estimating the sudden increase in the external volume of the Berthelot tube at this instant.
The results show that the critical tension occurring in any one tube varies considerably in successive experiments ; this variation is liable to be as great as 30 atmospheres. Furthermore the magnitude of this tension varies from tube to tube ; some tubes can sustain 60 atmospheres while others are incapable of sustaining even 5 atmospheres.
Experiments with tubes constructed from steel gave substantially similar results. So also did glass tubes containing suspensions of ultramarine powder in water and carbontetrachloride with water.
Furthermore, pre-compression of the liquid has no detectable effect on the critical tension. Neither has rate of build-up of the applied tension, nor mechanical shock.
An incidental result has been the verification of the equality of the extensibility and compressibility of water.

The unrestricted Hartree–Fock method. By W. Marshall.
The unrestricted Hartree–Fock method is a convenient method of calculating neutron form factors and hyperfine interactions, but because the method gives wavefunctions which are not eigenfunctions of S^2, the validity of it must be questioned. It is shown that the unrestricted Hartree–Fock method gives spin densities which are approximately correct to first order provided certain exchange energies are small relative to ' promotion ' energies. Furthermore it is shown that the wavefunctions obtained must be used directly and that it is a poor approximation to project out the unwanted parts after the energy minimization procedure has been performed.

Quantum theory of magnetoresistance. I: Low fields. By R. B. Stinchcombe.
The conventional treatment of magnetoresistance is based upon the Boltzmann equation for a distribution function $f(\mathbf{k})$, and an equation which gives the average current in terms of $f(\mathbf{k})$. With the usual definition of $f(\mathbf{k})$ neither equation is exact : the derivation of the Boltzmann equation requires $\omega\tau < 1$ where ω is the cyclotron frequency and τ is the relaxation time. In this paper a representation is proposed which exploits the properties of homogeneous systems in a uniform magnetic field. We redefine $f(\mathbf{k})$ as the diagonal element of the density matrix in the new representation. Then the usual equation for obtaining the current becomes exact. Proceeding from the equation of motion of the density matrix we then give a weak-coupling derivation of the Boltzmann equation in the manner used by Kohn–Luttinger in 1957 for field-free systems. The derivation is restricted to the case of non-interacting carriers elastically scattered by impurities or lattice vibrations, and moving in a lattice which in the absence of the magnetic field gives rise to non-overlapping bands. The conductivity yielded by this method is found to be accurate as long as $\hbar\omega$, $\hbar/\tau$ are small compared to the Fermi energy, and $\hbar\omega$ is less than the thermal energy. The condition $\omega\tau < 1$ does not arise.

Horizontal refraction in a three-dimensional medium of variable stratification. By D. E. Weston.
In the sea the repeated horizontal deflection of a sound ray due to reflection at a sloping bottom produces a curvature of the horizontal path. The reflection angles in three dimensions are calculated for a sloping bottom or sound velocity interface. Even if the stratification varies in both horizontal directions there is for slow variations a simple relation between the changes in vertical and horizontal ray angle. It is then shown that the horizontal curvature may be predicted by associating a refractive index or phase velocity with each horizontal position. A formula for intensity and some illustrative problems are presented. For example it is shown that on reflection from a coastline the vertical ray angle at closest approach is equal to half the total horizontal angle through which the ray is turned.

LETTERS TO THE EDITOR

Dislocation relaxation in zinc at low temperatures. By B. K. Agrawal and G. S. Verma.
The spin of a new level in ^{24}Mg. By C. Broude and H. E. Gove.
The effective number of electrons in the π band of graphite. By T. E. Peacock.
The threshold of the ^{13}C(^{3}He,n)^{15}O reaction. By J. H. Towle and B. E. F. Macefield.

SPECTROSCOPIC STUDIES USING TIME RESOLUTION TECHNIQUES

The Applied Spectroscopy Group and the Manchester and District Branch are arranging a joint all-day meeting on the above subject to be held on Friday, June 16, 1961, in the Lecture Hall of the Manchester Literary and Philosophical Society.

The following papers will be presented :-

1. Spectroscopic studies of impurity ions in Zeta: R. Wilson (*Atomic Energy Research Establishment, Harwell*).
2. Some applications of sub-microsecond spectroscopy to gas discharge problems: A. H. Gabriel, A.Inst.P. (*Atomic Weapons Research Establishment, Aldermaston*).
3. Time resolved spectroscopy with transient discharges: J. D. Craggs, F.Inst.P. (*University of Liverpool*).
4. Development and uses of time resolved spectrographs at the U.S. Naval Research Laboratory: F. D. Harrington (*U.S. Naval Research Laboratory*).
5. Some recent time resolved spectroscopic studies of the sceptre discharge: R. V. Williams, A.Inst.P. (*Associated Electrical Industries, Aldermaston*).
6. Spectroscopy of a plasma produced by rapid magnetic compression: N. J. Peacock, A.Inst.P. (*Atomic Weapons Research Establishment, Aldermaston*).
7. A synchronised direct reading spectrometer–spark system for time resolved spectra with application to the analysis of copper in aluminium alloys: A. Strasheim & W. W. Schroeder (*National Physical Research Laboratory, South Africa*).

The Secretary of the Applied Spectroscopy Group, Dr. L. Bovey, Building 392.2, A.E.R.E., Harwell, Didcot, Berks., would be glad to give further information.

Registration is necessary and detailed program and application forms will be available from the Administration Assistant of the Institute and Society in early May.

The National College for Heating, Ventilating, Refrigeration and Fan Engineering

at the

BOROUGH POLYTECHNIC,
Borough Road, London, S.E.1.

Director:
JAMES E. GARSIDE, M.Sc.Tech., Ph.D., F.R.I.C., F.I.M., F.Inst.F.

Head of College:
DAVID R. SCOTT, M.Sc., Ph.D., M.Inst.R., A.M.I.H.V.E., A.Inst.P., A.M.I.Min.E., A.M.E.M.E.

British Refrigeration Association Research Fellowship

The Governors invite applications from graduates or from those graduating this year in Engineering or Physics for the above Fellowship, tenable at the National College. The successful applicant will be required to undertake research on Heat Transfer in Refrigeration Evaporators.

The value of the Fellowship is at present £800 per annum, as this is a Fellowship the income is not taxable; the Fellowship is awarded for a minimum period of two years. Should he desire, the Fellow will be further permitted to undertake six hours lecturing per week, which would augment his income by approximately £150 per annum. The value of the Award is under review and may be subject to an increase after one year.

Where University regulations permit the Fellow will be encouraged to present his work for a higher degree.

The Fellowship provides a suitable opening for an ambitious young man wishing to enter the small, but well-paid, field of Refrigeration Engineering in which many excellent opportunities exist.

Further information is obtainable from the undersigned, to whom application should be made as soon as possible.

FREDK. J. PACKER,
Clerk to the Governors.

RESEARCH IN ADVANCED MINING TECHNIQUES

PHYSICISTS AND ENGINEERS are required at the National Coal Board's Mining Research Establishment at Isleworth for research on instruments for the control of working conditions and on instrumentation of mining machines and equipment.

Vacancies exist for men interested in the fields of:

CLASSICAL PHYSICS
(X.2192E)
salary range £770 – £1,700

ELECTRONICS
(X.2193E)
salary range £770 – £1,700

There is also a vacancy at a higher level in the field of

ELECTRONICS
(X.2194E)
salary range £1,640 – £2,300

Applicants should have a good honours degree in Physics or Electrical Engineering, or expect to graduate this year. There are attractive conditions of service; starting salary will be according to qualifications and experience within the ranges quoted above. Please write, giving full details and quoting appropriate reference number, to **Director, Mining Research Establishment, National Coal Board, Worton Hall, Isleworth, Middlesex.**

PHYSICISTS IN GOVERNMENT SERVICE

A SCIENTIFIC CAREER SECOND TO NONE

Following are examples of vacancies at

SCIENTIFIC OFFICER (£738–£1,222) or

SENIOR SCIENTIFIC OFFICER (£1,342–£1,654)

level now available:—

ROYAL AIRCRAFT ESTABLISHMENT, Farnborough, Hants —research on new methods of INERTIAL SPACE REFERENCE for inertial navigation, aimed at achieving a significant advance over the current technique of flotation gyroscopes.

NATIONAL PHYSICAL LABORATORY, Teddington, Middlesex—work on static or dynamic properties of HIGH POLYMER materials.

ADMIRALTY UNDERWATER WEAPONS ESTABLISHMENT, Portland, Dorset—research in UNDERWATER NOISE and signal intensity measurements. Requires experience in ELECTRONICS, interest in ACOUSTICS and some knowledge of digital analysis, vibration theory, or spectrum analysis.

ARMAMENT RESEARCH and DEVELOPMENT ESTABLISHMENT, Fort Halstead, Sevenoaks, Kent — basic investigations of OPTICAL SYSTEMS in INFRARED and PHOTOGRAPHIC OPTICS.

There are many other vacancies in PHYSICS, ENGINEERING and most other scientific disciplines. All posts carry a pension. Good promotion prospects. Full particulars from Civil Service Commission (Scientific Branch), 17 North Audley Street, London, W.1.

AIR MINISTRY
SCIENTIFIC ADVISER'S DEPARTMENT

AIR MINISTRY require unestablished SENIOR SCIENTIFIC, SCIENTIFIC OFFICER and EXPERIMENTAL OFFICERS in SCIENTIFIC ADVISER'S Department. Qualifications: Senior Scientific and Scientific Officers should have 1st or 2nd Hons. Degree in one of the subjects specified. Experimental Officers should be between 26 and 31, and have pass degree, H.N.C. or G.C.E. "A" Level including at least one of the subjects specified. FOUR SCIENTIFIC OFFICER POSTS at A.M. Headquarters, WHITEHALL for GRADUATES in MATHEMATICS or PHYSICS. Post A—in Strategic Offense and Atomic Section, involving cost/effectiveness studies of offensive systems, studies on strategy of R.A.F. offensive operations, and of atomic effects and target response. Mathematician preferred. Post B—in Air Defence and Electronics Section involving cost/effectiveness studies of defensive systems and detailed electronic studies of radar, electronic countermeasures, and infra-red. Physicist preferred. Post C—in Strategic Studies and Anti-Submarine Warfare Section, involving studies of interplay of offense and defence, and the requirements of nuclear submarine detection. Post D—in Limited War Section, involving studies of tactical aircraft, tactical weapons systems and limited form of war games in tactical sphere. THREE SENIOR SCIENTIFIC OR SCIENTIFIC OFFICER posts on staff of OPERATIONAL RESEARCH Branch at BOMBER COMMAND, High Wycombe, for GRADUATES in MATHEMATICS, PHYSICS or ENGINEERING. Post E—at Command H.Q. involving work on evaluation, use and operation of airborne and ground electronic equipment. Good electronics background required, preferably with experience on airborne and ground radar. Post F—at Command H.Q. involving work on problems of effectiveness of Medium Bomber Force and in programming and organization of an Elliott 402 computer. Good mathematical background required. Post G—involving work on trials of Bluesteel and also work at Bomber Command Development Unit at Finningley, Yorks. TWO EXPERIMENTAL OFFICERS for Post H—at H.Q. BOMBER COMMAND, High Wycombe, to assist in computer programming to train other programmers and to participate in work involving bombing calculations, defect recording systems, nuclear fallout profiles, etc. Be interested in problems of data handling and have qualifications in mathematics, physics or engineering. Post I—at H.Q. TECHNICAL TRAINING COMMAND, Brampton, Hunts., concerned with collection and analysis of data, and conducting experiments in training of technicians. Background and qualifications in social sciences with some knowledge of statistics preferred but qualifications and experience in electronic engineering acceptable. Salaries: National rate—Senior Scientific Officers £1,342–£1,654. Scientific Officers £738–£1,222. Experimental Officers £1,087–£1,336. £55–£65 more for posts in London. Forms from Ministry of Labour, Technical and Scientific Register (K), 26 King Street, London, S.W.1 (quoting A 128/1A and appropriate Post reference). Closing date May 12, 1961.

IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY
PHYSICS DEPARTMENT

Applications are invited for the following posts in the photoelectronics section:—LECTURER. Salary in range £1,050 × £50 to £1,400 × £75 to £1,550 (bar) × £75 to £1,850 per annum, plus £60 per annum London Allowance and Family Allowance of £50 per child per annum. F.S.S.U. membership. Duties include teaching General Physics and special Advanced Course, research in application of photoelectronics to nuclear physics, astronomy, space research, etc. RESEARCH ASSISTANT (Academic) to assist in research in the fields of vacuum physics and photoelectronics. A good degree essential and some research experience preferable. Salary in range £700 to £1,100 per annum depending upon qualifications, plus Family Allowance. F.S.S.U. membership. Apply, with full personal and academic details and names of two referees, to Professor J. D. McGee, Physics Department, Imperial College of Science and Technology, London, S.W.7.

RESEARCH
PHYSICS AND METALLURGY

THE INTERNATIONAL NICKEL COMPANY (MOND) LTD., invites applications from Physicists, for a position in its Development and Research Department Laboratory in Birmingham, to undertake investigations into the development and evaluation of new materials which will provide the magnetic, elastic and other physical properties required by modern industry in the special materials now used in the construction of all types of equipment. The work will also involve an interest in studies of the structure of alloys, using electron microscopic, electron microprobe and X-ray crystallographic techniques. The post carries responsibility for the planning and conduct of research. Publication of the successful candidate's work will be encouraged.

Applications are invited from candidates possessing an Honours degree in Physics or equivalent qualification. Pension and assurance schemes are in operation and, in appropriate cases, assistance can be given for housing. Applications, which will be treated in confidence, should give details of age, qualifications, experience and salary required.

They should be addressed to:

The Research Manager, D. and R. Dept.,
THE INTERNATIONAL NICKEL COMPANY (MOND) LTD.,
Thames House, Millbank, London, S.W.1
Please mark envelope "Confidential L.89".

PRODUCTS APPLICATION

As a result of continuing expansion, a

PHYSICIST

with a good honours degree, postgraduate, academic or industrial training in laboratory techniques, preferably concerned with optics and lighting, is required to supervise the building and calibration of an artificial sky and to carry out model experiments.

Apply to the **Personnel Officer (Graduate Recruitment)**

PILKINGTON BROTHERS LIMITED
Glass Manufacturers
ST. HELENS, Lancs.

AUSTRALIA

COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION

RESEARCH PHYSICIST

The Organization's Division of Metrology, National Standards Laboratory, Sydney, N.S.W., invites applications for the position of Research Physicist in the Interferometry Section from Honours graduates, majoring in Physics (or equivalent qualifications) with some years of postgraduate research experience.

The appointee is required for research in interference spectroscopy and the development of new forms of light sources. These sources may include atomic beams and other types of sources that emit intense and highly monochromatic radiation suitable for interferometry at large path differences. The Section has a well-equipped vacuum coating laboratory and is also engaged in making isotopic light sources.

Salary: dependent on qualifications and experience within the ranges:—£A1,510 – £2,265 p.a. or £A2,395 – £2,720 p.a.

Salary for a woman will be £A180 p.a. less than corresponding rates for men.

Promotion within C.S.I.R.O. is by merit and may ultimately go beyond the upper limit of the scale within which the original appointment is made.

Fares paid. Further particulars of conditions, etc., supplied on application to:—Mr. E. J. Drake, Chief Scientific Liaison Officer, Australian Scientific Liaison Office, Africa House, Kingsway, London, W.C.2, to whom applications (quoting Appointment No. 750/222) should be addressed by **May 13, 1961.**

UNIVERSITY COLLEGE OF SOUTH WALES AND MONMOUTHSHIRE

Applications are invited for the post of LECTURER OR ASSISTANT LECTURER, in accordance with age and qualifications, in the Department of Physics from October 1, 1961. Further particulars may be obtained from the Registrar to whom six copies of applications (containing the names of three referees) should be sent not later than April 21, 1961. E. R. Evans, Registrar, Cathays Park, Cardiff.

EXPERIMENTAL STRESS ANALYST, preferably with a physics degree, is required for research and development work on Steam Turbines. He will be expected to apply conventional methods of stress analysis and will be concerned with the development and application of new methods. This is a new post in the expanding laboratory of the Power Plant Division at the Erith Works and offers excellent opportunities for personal initiative. Apply Personnel Manager (GAL), The General Electric Co. Ltd., Erith, Kent.

Applications are invited from a PHYSICIST or PHYSICAL CHEMIST to undertake research in connection with problems in food manufacture. Initial duties will be concerned with investigations into the rate of diffusion of moisture during the drying of confectionery and the person appointed will be expected to develop experimental techniques appropriate to the study. The candidate must hold a University degree and should have some experience in the conduct of research. Apply in writing to the Director of Research, BRITISH FOOD MANUFACTURING INDUSTRIES RESEARCH ASSOCIATION, Randalls Road, Leatherhead, Surrey, giving details of qualifications and salary expected. The post carries comparable pension and life insurance rights. Applications should be marked " Private and Confidential ".

IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY POSTDOCTORAL FELLOWSHIP IN FLAME SPECTROSCOPY

Applications are invited for a Postdoctoral Fellowship for research in Flame Spectroscopy or a related subject, sponsored by General Motors Corporation, Detroit, U.S.A., in the Department of Chemical Engineering, Imperial College, under the supervision of Dr. A. G. Gaydon, F.R.S. Value £900 p.a. with family allowances and F.S.S.U. Further particulars from Dr. A. G. Gaydon, Imperial College, London, S.W.7.

UNIVERSITY COLLEGE OF NORTH WALES, BANGOR

Applications are invited for a LECTURESHIP IN THE DEPARTMENT OF PHYSICS. The main research interests in the Department are Solid-state Physics and Molecular Physics. The salary scale is £1,050 × £50 – £1,400 × £75 – £1,850, and the initial salary will be according to qualifications and experience. In addition there are F.S.S.U. benefits and family allowances. The appointment will date from October 1, 1961. Two copies of the application should reach the Registrar, University College of North Wales, Bangor, from whom further particulars may be obtained, not later than April 24, 1961.

BRADFORD INSTITUTE OF TECHNOLOGY DEPARTMENT OF PHYSICS

Applications are invited for the posts of SENIOR LECTURER IN PHYSICS and LECTURER IN PHYSICS. These posts are newly established ones resulting from the extension of the work of the Department. Candidates should be well-qualified physicists; experience of the application of physics in industry would be a strong recommendation. The Department is increasingly concerned with courses for the Diploma in Technology in Applied Physics, Engineering, Industrial Chemistry and Mathematics; the successful candidates will share in this work and have the opportunity to co-operate in research. Salary Scale—Senior Lecturer £1,550 to £1,750 per annum. Lecturer £1,370 to £1,550 per annum. Previous industrial or research experience at a suitable level will be taken into account in fixing the commencing salary. Further details and forms of application, which should be returned as soon as possible, may be obtained from the Registrar (Department X), Bradford Institute of Technology, Bradford, 7. Henry Patten, Clerk to the Governors.

THE COLLEGE OF AERONAUTICS

Applications are invited for a RESEARCH FELLOW in the DEPARTMENT OF MATERIALS to undertake research on the fundamental deformation and annealing mechanisms in GRAPHITE. Candidates should possess a first degree in physics or metallurgy, and the person appointed will be permitted to submit his work for a higher degree. Salary up to £1,500 per annum, depending on qualifications and experience, with superannuation under F.S.S.U. and family allowance. Appointment will be made initially for three years with prospects of continuation. Applications containing full particulars should be addressed to the Recorder, The College of Aeronautics, Cranfield, Bletchley, Bucks.

UNIVERSITY OF CAMBRIDGE
CAVENDISH LABORATORY
ASSISTANT DIRECTORS OF RESEARCH IN ELECTRON MICROSCOPY

Applications are invited for the position of Assistant Director of Research in the Electron Microscope Section of the Cavendish Laboratory. Candidates should have had post-doctoral research experience, preferably in the application of the electron microscope and related physical methods in Biology or Medicine. The appointment will be for five years in the first instance. Salary range £1,250 – £1,850, with F.S.S.U. participation and Family Allowance. Further particulars may be obtained from the Secretary of the Appointments Committee of the Faculty of Physics and Chemistry, Chemical Laboratory, Lensfield Road, Cambridge, to whom applications should be sent not later than May 1, 1961.

UNIVERSITY OF GLASGOW
UNIVERSITY STUDENTSHIPS AND FELLOWSHIPS

Applications are invited for University Studentships and Fellowships for experimental or theoretical research in Solid State Physics. Salary scale : STUDENTSHIPS: £350 – £600 per annum, according to qualifications with a tenure of three years. FELLOWSHIPS: £700–£1,000 per annum, according to qualifications. Tenure three years on appointment, with possible renewal for further period of two years. These Fellowships will be superannuated under the F.S.S.U. Applications stating age, academic qualifications, research experience and names of two referees, should be sent to the Professor of Natural Philosophy, University of Glasgow, before May 13, 1961.

COURSES

ROTHERHAM
COLLEGE OF TECHNOLOGY
DEPARTMENT OF PHYSICS

A short Full-time Course in
HIGH VACUUM TECHNOLOGY
will be held during the period
MONDAY, 26TH JUNE TO
FRIDAY, 30TH JUNE, 1961
from 9.30 a.m. to 5.00 p.m. daily

The course is designed to cover the fundamentals of the production and measurement of high vacua. It should be of particular interest to those requiring high vacuum as an ancillary to their main interest. Full details of the course may be obtained from the Registrar, College of Technology, Howard Street, Rotherham.

UNIVERSITY OF CAMBRIDGE
DEPARTMENT OF ENGINEERING
POSTGRADUATE COURSE IN CONTROL ENGINEERING

The 1961-62 Postgraduate Course in Control Engineering will begin on October 9, 1961, and will last approximately nine months. This course has been established in order to meet the needs of Industry for men trained to a high standard in the theoretical principles and practical application of automatic control and to afford opportunity for study of advanced techniques and modern development in the general field of Control Engineer, sometimes called "Systems Engineering". The number of sudents will be limited and applications must reach the Secretary of the Department not later than May 31, 1961. Candidates should hold a degree in Engineering or a suitable alternative qualification and have had at least two years' practical training and experience. They may be required to attend for interview in Cambridge. Further details and forms of application for admission may be obtained from the Secretary, Cambridge University Department of Engineering, Trumpington Street, Cambridge.

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Research Laboratories

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PHYSICIST
or
CHEMIST

for advanced development in
FILM RESISTORS

Research or production experience in this or closely related fields would be very desirable.

The post carries an attractive salary according to experience and background, with excellent working conditions in a well equipped laboratory. Evening/week-end interviews, if required, by arrangement.

Please apply to

Personnel Manager,
G. V. Planer Ltd.,
Windmill Road,
Sunbury-on-Thames,
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(Sunbury-on-Thames 2266)

BIRKBECK COLLEGE
(UNIVERSITY OF LONDON)

SESSION 1961-62 BEGINS
MONDAY, OCTOBER 2, 1961

Part-time (evening) Courses provided for Internal degrees in the Faculties of Arts and Science. Facilities also provided for full-time and part-time students reading for

(i) Higher degrees in Arts and Science.

(ii) M.Sc. Crystallography by examination.

(iii) Academic postgraduate Diplomas in Psychology, Numerical Analysis and Statistics.

The Department of Scientific and Industrial Research has accepted the Postgraduate Diplomas courses in Psychology and Numerical Analysis and the M.Sc. crystallography course, as suitable for tenure of its Advanced Course Studentships. Students intending to read for Higher Degrees in Science by thesis are invited to enquire of the College whether it has available any D.S.I.R. Research Studentships. Applications for admission to the College should be made before June 1.

Pamphlet and form of application may be obtained from **The Registrar, Birkbeck College, Malet Street, W.C.1.**

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